Electronic Services - Los Angeles
M13625X

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NEWPORT LABORATORIES

Series 50, 55, 60 and 70 Amplifiers

INSTRUCTION MANUAL

Newport Laboratories, Inc., 630 E. Young St., Santa Ana, Calif. 92705

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Appendix

Special Characteristics of Given Jobs

Diagrams

# PREFACE

The main body of this manual applies generally to all Series 50, 55, 60 and 70 amplifiers. Information defining individual variants is provided in the appendix. Because of the numerous variations within these amplifier series, it is advisable to consult the appendix first and then study the rest of the manual in light of the particular configuration for which these manuals are furnished.

These are highly sensitive amplifiers for use in making very accurate measurements. To preserve data quality, the amplifiers must be properly understood and used, so a thorough study of this manual is essential to any user. Particular care should be devoted to grounding and shielding of the cables and other equipment used with the amplifiers.

The four amplifier series are distinguished from one another by their packaging and by the magnitude of the common-mode voltage they are able to reject. These characteristics are summarized in the table below.

| | Series 50 | Series 55 | Series 60 | Series 70 |
|---|---|---|---|---|
| common-mode voltage rejected | ±10 v | ±300 v | ±10 v | ±300 v |
| package style | 3" x 6" printed circuit card | | 1.7" x 3.5" x 16" enclosed instrument module | |
| 19" rack mounting | twenty per 3.5" row | | ten per 3.5" row | |

Series 60 and 70 amplifiers, being in larger packages, have available certain options which cannot be provided in Series 50 and 55, notably:

1. Self-contained power supplies for operation from the AC power line.

2. Switchable bandwidth.

3. 3-pole and 4-pole filtering.

4. Multiple outputs buffered by post-amplifiers.

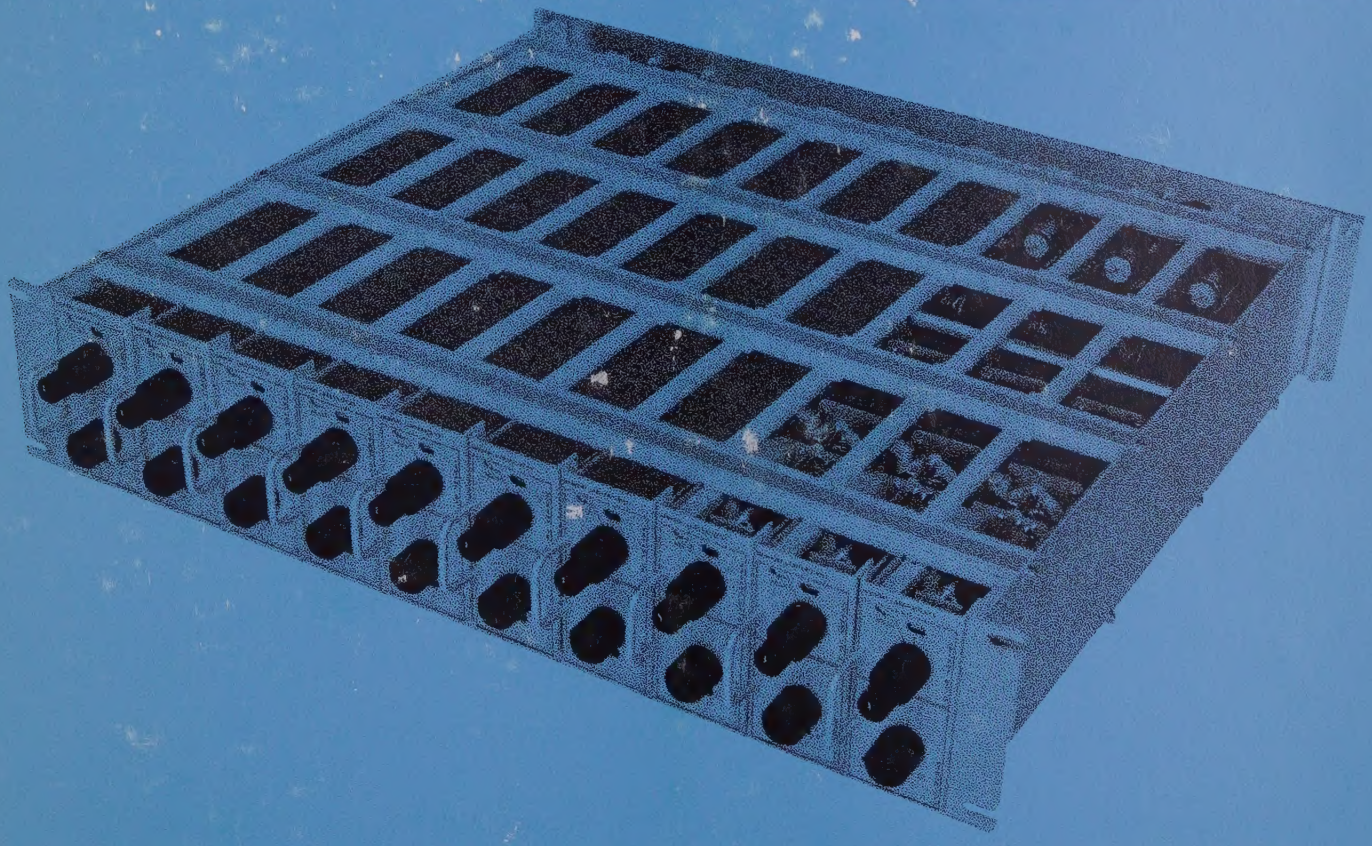
GSA Contract GS-00S-75311

# Series 60 and 70 DC DATA AMPLIFIERS

30 M$\Omega$ $Z_{in}$ at gains from 1 to 5000 ▪ 133 db rejection of 300 volts, 60 Hz common-mode at gain = 1000; 72 db at 100 kHz ▪ 100 kHz bandwidth ▪ 75 $\mu$sec settling time ▪ 0.4 $\mu$v/°C input drift ▪ ten amplifiers in 3.5″ panel height ▪

## Options including:

4-pole (24 db/octave) active filter ▪ input calibration switching ▪ two continuous outputs, plus a commutated output ▪ switched and/or continuous gain adjustment ▪ zero suppression up to 10X full scale ▪ oscillograph calibrator, for scaling in convenient units ▪ selectable, automatic output current limiting ▪ provision for a galvanometer damping network ▪



NEWPORT LABORATORIES INC.

Santa Ana, California

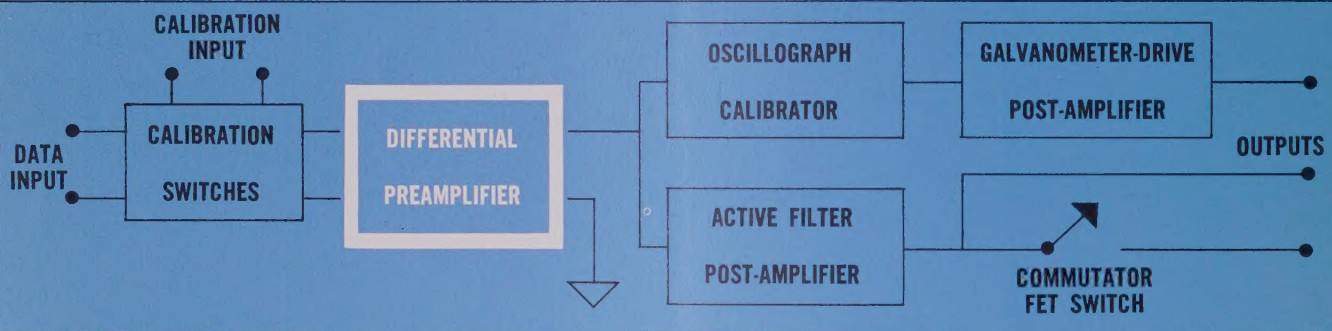
# Series 60 and 70 AMPLIFIERS

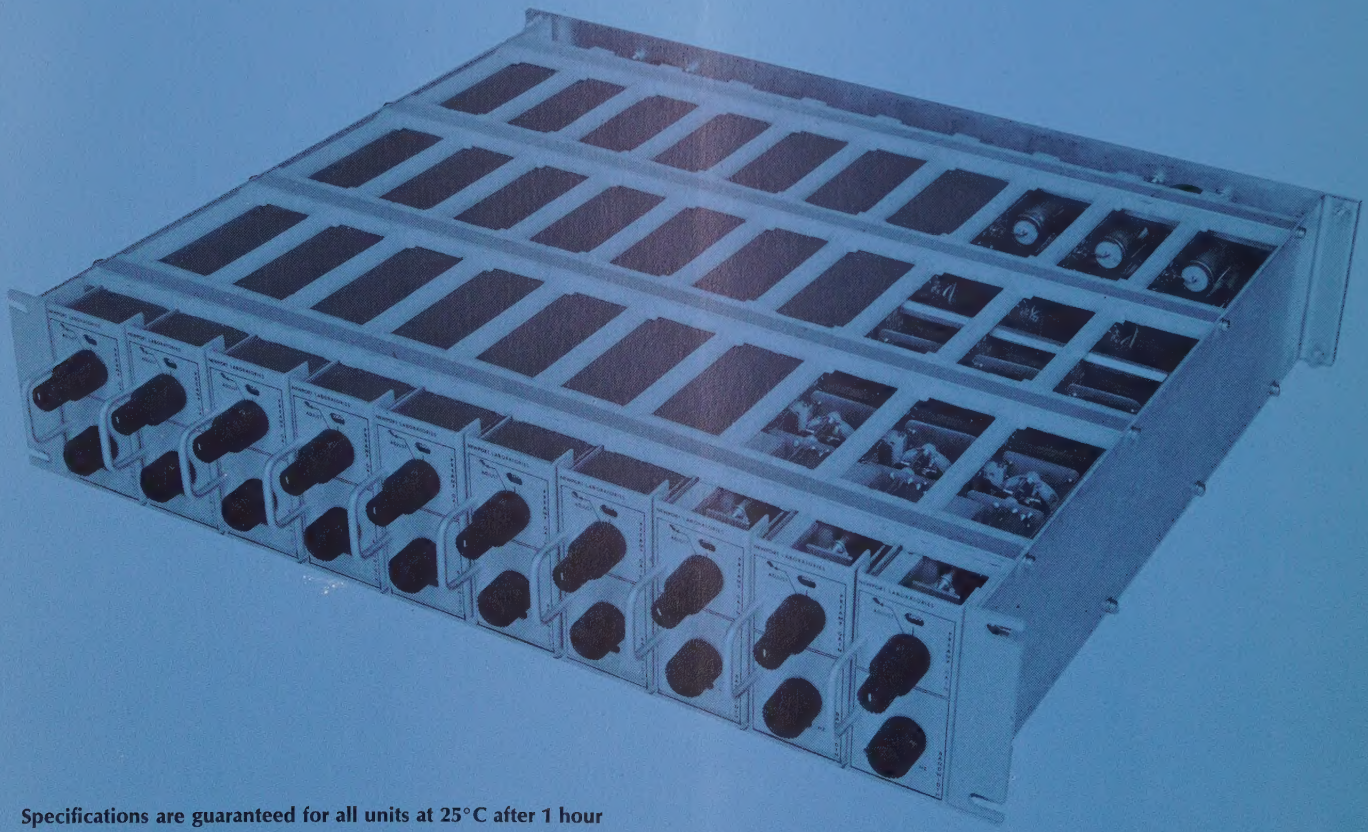
These instruments accept low-level, differential signals from transducers or electrical equipment. They produce 10 volts output with up to 100 ma current capability. Series 70 amplifiers reject up to 300 volts common-mode. Series 60 amplifiers, at lesser cost, reject up to 10 volts common-mode. With respect to packaging and electrical performance other than common-mode rejection, the two series are the same.

The fundamental element is a differential preamplifier, to which building-blocks may be added as shown below. The building-block complement in a given amplifier is specified by the model number, as described on the price list.

There are six basic amplifier models in each series, plus additional options. Post-amplifiers may be used as their names imply or may simply serve as buffers. Packaging is the same for all models and options.

Common-mode rejection and almost all the gain are provided in the differential preamplifier. Accuracy specifications for the differential preamplifier govern all outputs, except as errors associated with options are explicitly specified. Bandwidth control is achieved by active filtering in the differential preamplifier or in the filter post-amplifier—or, to obtain 3-pole or 4-pole response, by filter poles in both places, with all poles controlled by one switch in amplifiers having switchable bandwidth.



**Specifications are guaranteed for all units at 25°C after 1 hour warmup.**

**Definitions:**
- **%FS, percent of ±10v RTO which is full scale**
- **%R, percent of reading**
- **RTI, referred to the input**
- **RTO, referred to the output**

# DIFFERENTIAL PREAMPLIFIER

## DIFFERENTIAL INPUT

The input source may be either floating or grounded; no bias-current return path is required.

Impedance: 30 MΩ resistance paralleled by 200 pf

Maximum Overvoltage Without Damage: 1000 times full scale or ±25 volts peak, whichever is less. (See Option F for input protection.)

## COMMON MODE

(Common-mode voltage is defined as the average of the voltages on the two signal inputs, with respect to output ground.)

Common-Mode Rejection

| | CMR AT GAIN = 1000 | | RTO ERROR PER VOLT C M V | |
|---|---|---|---|---|
| | 0Ω SOURCE | 1KΩ SOURCE | 0Ω SOURCE, ANY GAIN | 1KΩ SOURCE, GAIN = 1000 |
| DC | 135 db | 131 db | 0.18 mv | 0.28 mv |
| 60 Hz | 133 db | 123 db | 0.22 mv | 0.71 mv |
| 400 Hz | 123 db | 107 db | 0.71 mv | 4.5 mv |
| 100 kHz | 72 db | 63 db | 250 mv | 710 mv |

Series 70 Maximum Common-Mode Voltage: ±300 volts peak rejected.

Series 60 Maximum Common-Mode Voltage

**Rejected:** ±10 volts peak

**Without Damage:** ±25 volts peak on either input with respect to output ground (See Option F for input protection)

DC offset due to 1 volt p-p common-mode voltage: 1μv RTI shift occurs at not less than 100 kHz.

Guarded Impedance from Either Signal Input to Output Ground: 5GΩ shunted by 2 pf

## DC GAIN

Single, fixed setting or up to 12 switched settings, A options.

Range of Settings: 1 to 5000

Standard Value Sequences, optional: decades or 1, 3, 10 . . . or 1, 2, 5, 10 . . .

Error Versus

**Initial Setting, optional:** ±0.1 %R for all gains; or ±0.01 %R for gains up to 1000 and ±0.1 %R for gains > 1000

(Gain variation with time and temperature is stated below for gains up to 1000. For gains > 1000, such errors increase proportionally with the increase in gain; e.g., 5X increase at gain = 5000.)

**Time:** ±0.01 %R per month ±0.02 %R per 6 months

**Temperature:** ±0.002 %R per °C

Nonlinearity:

±0.005% FS for 2 ≤ gain ≤ 1000
±0.01% FS for gain = 1
±0.01% FS/thousand for gain > 1000

Continuous, Fine Gain Adjustment (screwdriver), H options

**Range:** ±0.4 %R

**Resolution:** 0.005 %R

Continuous, Coarse Gain Adjustment (screwdriver), H options

**Range:** increase gain as required (up to X10) to cover the range between switch steps.

**Resolution**

**At X1 Setting:** 0.05 %R

**At Maximum Gain Setting**

X2.5: 0.2 %R X3.4: 0.3 %R X10: 1.2 %R

**Stability versus**

**Time:** ±0.5 %R per month ±1 %R per 6 months

**Temperature:** ±0.02 %R per °C

Continuous Adjustment Bypass, H options, 3-position switch:

1. Gain steps calibrated as indicated on the gain switch – coarse and fine adjustments inoperative.
2. Fine adjustment operative, but not coarse.
3. Both coarse and fine adjustments operative.

## DYNAMIC RESPONSE

Small-Signal Bandwidth, $f_c$ = −3 db corner frequency: single, fixed setting or up to 9 switched settings, B options.

**Range of Settings:** 10 Hz to 100 kHz

**Standard Value Sequences,** optional: decades or 10 Hz, 30 Hz, 100 Hz . . . 100 kHz.

**Effect of Very Large Gain:** Maximum bandwidth is reduced in proportion to the increase of switched gain above 1000. If the gain switch is set at 5000, maximum bandwidth is 20 kHz.

**Number of Poles,** optional: 1 or 2

**Concerning 3-pole and 4-pole Filters:** Filters having 3 or (optionally) 4 poles are made with just one or two poles in the differential preamplifier and the other two poles in the active filter postamplifier. Optimum characteristics are obtained at the output from the active-filter post-amplifier; i.e., Butterworth or Bessel characteristics with −3 db corner at the nominal $f_c$ and 18 or 24 db/octave rolloff above $f_c$. This results in the below tabulated characteristics at the output from the differential preamplifier.

| RESPONSE AT ACTIVE-FILTER POST-AMPLIFIER OUTPUT | PREAMPLIFIER RESPONSE | | |
|---|---|---|---|
| | ROLLOFF db/OCTAVE | −3 db CORNER FREQUENCY | DAMPING FACTOR |
| 3-pole Bessel | 6 | 1.3 $f_c$ | n/a |
| 3-pole Butterworth | 6 | $f_c$ | n/a |
| 4-pole Bessel | 12 | $f_c$ | 0.95 |
| 4-pole Butterworth | 12 | 0.7 $f_c$ | 0.9 |

Slewing Limit

**RTO:** 3.1 volts per microsecond (full-scale sinusoidal response undistorted to 50 kHz; 10 volts p-p sinusoidal response undistorted to 100 kHz)

**RTI:** 1 volt per microsecond, limits full-scale response only at gains less than 3

Settling Time in response to a 10-volt RTO full-scale step, with 100 kHz, 1-pole bandwidth

**To within 0.1% residual error** at switched gain settings up to 1000: 75 microseconds.

**To within 0.01% residual error**

Switched gain = 1: 130 microseconds

Switched gain = 2: 120 microseconds

Switched gain = 5 to 1000: 110 microseconds

Recovery from Overdrive of 5 times full scale: 400 μs to within 0.1 %FS at bandwidth = 100 kHz and gain = 1000. Recovery is faster at lower gains.

## ZERO OFFSET (RTI measured at gain = 1000, RTO at unity gain) versus

Initial Setting: (±1.0 μv±1 na) RTI ±0.5 mv RTO
(Input zero potentiometer is provided)

Time: [(±2 μv ±1 na) RTI ±0.2 mv RTO] per day
[(±10 μv ±2 na) RTI ±0.5 mv RTO] per month

Temperature: [(±0.4 μv ±0.5 na) RTI ±0.15 mv RTO] per °C

Power Supply: [(±0.2 μv ±0.2 na) RTI ±0.5 mv RTO] per % change in DC supply. No sensitivity to ±10% AC line variation when a Newport Laboratories integral power supply (P option) is used.

Effect of Continuous, Coarse Gain Adjustment: All RTO offset errors are multiplied by the gain attributable to the continuous, coarse gain adjustment.

## AC NOISE with 1 kilohm source impedance

(RTI measured at gain = 1000, RTO at unity gain. Noise from DC to 0.1 Hz is considered zero offset drift.)

0.1 Hz to 10 Hz: 1 μv RTI and 0.5 mv RTO, peak 99.9% confidence

0.1 Hz to 100 Hz: 2 μv RTI and 0.7 mv RTO, peak 99.9% confidence

0.1 Hz to 1 kHz: 1 μv RTI and 0.25 mv RTO, rms

0.1 Hz to 10 kHz: 3 μv RTI and 0.3 mv RTO, rms

0.1 Hz to 100 kHz: 10 μv RTI and 0.6 mv RTO, rms

Effect of Continuous, Coarse Gain Adjustment: All RTO noise errors are multiplied by the gain attributable to the continuous, coarse gain adjustment.

## OUTPUT CHARACTERISTICS

Impedance: 0.1 ohm in series with 5 microhenries

Voltage: ±10 volts full scale

Rated Current: 10 ma standard; 100 ma with Option J

Protection: Short-circuit current is limited safely.

Capacitive Load: No instability up to 1 microfarad.

## ACTIVE FILTER-POST AMPLIFIER

**DC Gain:** Unity

**Offset, Noise and DC Gain Error:** included within the tolerances on the differential preamplifier.

### Output

Impedance: 0.1 ohm in series with 5 microhenries

Voltage: ±10 volts full scale

Rated Current: 10 ma

Protection: Short-circuit current is limited safely

Capacitive Load: No instability up to 1 microfarad.

Dynamic Response:

**−3 db Bandwidths,** B options: 10 Hz, 30 Hz, 100 Hz . . . 100 kHz or decade steps

**Rolloff Slope,** B options: 12, 18 or 24 db/octave (in the 18 and 24 db/octave cases, part of the filtering takes place in the differential preamplifier).

**Multi-pole Response Shape,** C options: Bessel or Butterworth.

**Settling Time,** Add 55 μsec to differential preamplifier time.

## GALVANOMETER-DRIVE POST-AMPLIFIER

### DC Gain

| | | VARIABLE OPTIONS | | |
|---|---|---|---|---|
| | STANDARD | K1 | K2 | K3 |
| Range: | unity, fixed | 0.1 to 10 | 0.1 to 1 | 1 to 10 |
| Resolution: | not applicable | (0.2 ÷ gain) %R | (0.02 ÷ gain) %R | (0.2 ÷ gain) %R |

DC Gain Error: ±0.1 %R; calibrated at minimum settings for variable-gain K options.

**−3 db Bandwidth, single pole:** At least 300 kHz for gain <1; 300 kHz ÷ gain for gain >1

**Settling Time:** Add 55 μsec to differential preamplifier time.

**Noise and Zero Offset:** Included within the RTO tolerances of the differential preamplifier, times gain >1

### Input Offset Control, Option L

(Specifications refer to the input of the galvanometer-drive post-amplifier.)

Range: ±10 volts, screwdriver adjustment

Resolution: 5 millivolts

Stability versus

**Time:** ±10 mv per day ±25 mv per week

**Temperature:** ±5 mv per °C

### Output

Impedance: 0.1 ohm in series with 5 microhenries

Voltage: ±10 volts full scale

Rated Current: 100 ma, with standard current limiting. Provision is made for installation of a galvanometer damping network.

Automatic Current Limiting: 150 ma short-circuit current may be reduced to protect the galvanometer by changing a resistor.

Capacitive Load: No instability up to 1 microfarad.

## SALES REPRESENTATIVE

## OSCILLOGRAPH CALIBRATOR

A switch is employed at the input to the galvanometer-drive post-amplifier to apply calibration signals, so the galvanometer driver's gain and offset may be adjusted to produce graphic recordings in convenient units of the original parameter, such as 10 psi or 10°C per chart division. The six switch positions are used as follows:

1. Normal data input is measured.
2. Normal data input is disconnected, so the output goes to the offset determined by offset adjustment.
3. thru 6. A calibration signal of +1v, −1v, +10v or −10v DC is applied to the input of the galvanometer-drive post-amplifier, as reference for adjusting the galvanometer driver's gain. The normal data signal and the offset signal are disconnected in these positions. The calibration accuracy specifications below apply only to amplifiers with integral power supplies.

**Calibration Error versus**
**Initial Setting:** ±0.2 %R
**Time:** ±0.1 %R per day
±0.25 %R per week
**Temperature:** ±0.05 %R per °C

### Switched Input Attenuator, Option D

In Series 60 amplifiers, but not in Series 70, the attenuator is arranged to divide the common-mode input as well as the differential input. This enables Series 60 amplifiers also, when the attenuator is switched in, to reject 300 volts common-mode. Presence of the attenuator in the package reduces pre-amplifier common-mode rejection by 10 db when the attenuator is switched out.

Attenuation Factor: 0.01 ± (0.1%R)

Differential Input Impedance: 2MΩ || 100 pf

Common-Mode Input Impedance
**Series 60:** 1MΩ || 10 pf
**Series 70:** 5GΩ || 1.5 pf

Maximum Common-Mode Voltage: ±300 volts peak rejected

Common-Mode Rejection, DC to 60 Hz: 72 db

Frequency Response: 3 db down at 20 kHz

### Input Calibration Switching, E Options

Unless the oscillograph calibrator is included (pre-empting the same switch), a 3-position switch may be employed manually to disconnect the signal source and: (a) short the input to the differential preamplifier, or (b) connect the preamplifier input to an external calibration source. Presence of calibration switching in the package reduces the preamplifier's common-mode rejection by 10 db. In Series 70 amplifiers only, relays can be provided, instead of the manual switch, to effect remotely-controlled switching of the preamplifier input from the normal signal to an external calibration source. IC-compatible control levels are:

+2v or more, or open — DATA mode

+1v or less — CALIBRATE mode

### Input Protection, Option F

The amplifier is protected up to ±300 volts peak differential or common-mode input. In Series 60 amplifiers, fusing occurs in case of 50 volts on either input with respect to the other input or with respect to output ground. In Series 70 amplifiers, fusing occurs in case of 50 volts differential only.

### Output Commutator Switch, Option M

An additional output is formed by switching the output of the active filter post-amplifier in the dash 2, 4 or 6 models, or the output of the differential preamplifier in dash 1, 3 or 5 models. The unswitched output remains available. The switching device is a silicon field-effect transistor.

Switch Impedance
**Switch On:** 300 Ω
**Switch Off:** 1 GΩ shunted by 5 pf

Switch Drive
A two-input AND gate is provided so the amplifiers may be wired in a two-dimensional address matrix.

**Control Levels:** +2v or more turns the switch off (+18v maximum).
+1v or less turns the switch on.

**Delay: 3 μsec.**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# SECTION 3

## UNPACKING & INITIAL INSPECTION

Before it is opened, the shipping container should be inspected for damage or evidence of abuse. After the container is opened and the presence of all expected material is verified, each amplifier should be inspected for shipping damage in accordance with the checklist below. If any apparent damage is found, the carrier should be notified immediately to establish a record of suspected shipping damage in case an insurance claim should become necessary.

1. Manipulate the knobs and the handle on the front panel to be sure they are intact and properly tightened. If they are merely loosened, they may be re-tightened with a screwdriver or allen wrench. If knobs have been misaligned relative to the panel markings, they may be re-aligned after the switch is turned to a stop at either extreme.

2. Manipulate the shield covers and the fiberglass-epoxy circuit card to ascertain that all screws are securely fastened.

3. Visually inspect the entire unit for dents, abrasion, corrosion, or broken parts.

# SECTION 4
# PRECAUTIONS

These amplifiers are system components intended for use by technically skilled personnel. As such, they are vulnerable to abuses and oversights which are itemized here to the extent they can be foreseen.

## DO's

In case of mysterious offset, pickup, oscillations or interaction between amplifiers, refer to Sections 9 and 10 of this manual.

When concluding the adjustment of a potentiometer, oscillate the control slightly around the desired setting and leave it without any residual stresses. The lead screw mechanism is slightly flexible and the setting may creep after careless adjustment.

Be sure the connector is clean, free of corrosion and properly wired. In particular, before power is applied, be sure DC power is wired with correct polarity in the case of amplifiers not containing integral power supplies.

When using a non-polarized connector for bench test, be sure the connector is oriented correctly. Reversal of the connector end-for-end may cause damage by application of power to the signal input.

Be sure the shield of the data input cable is connected both at the amplifier and at the signal source.

Be sure rack adapters are installed right-side up. Pin 1 of the printed-circuit edge connectors should be on top.

Allow 30 minutes warmup time after power is turned on, before the amplifiers are calibrated or adjusted for zero offset.

Be sure to set the gain switch for maximum gain while the input offset is being adjusted to zero.

In driving a galvanometer, be sure the value at which output current is automatically limited by the amplifier is appropriate to the galvanometer in use.

DON'Ts

For differential amplification, don't connect the data input shield to local ground or output ground at the amplifier.

Don't operate in fields of great magnetic flux, such as near large, electric motors or generators.

Don't operate the amplifiers in an environment where other equipment generates much heat.

Avoid using a fan or otherwise subjecting the amplifiers to turbulent air currents. Natural convection suffices to cool the amplifiers, if vertical air flow is unimpeded and no heat generators are enclosed in the same space.

Don't attempt to force switches past stops.

Don't clean switch wafers with trichloroethylene or any hydrocarbon solvent which attacks the plastic, switch parts. Use isopropyl alcohol only.

Don't clean switch wafers without afterward re-lubricating the contact surfaces with a heavy, silicone oil.

Don't exceed voltage ratings on the signal input or power supply.

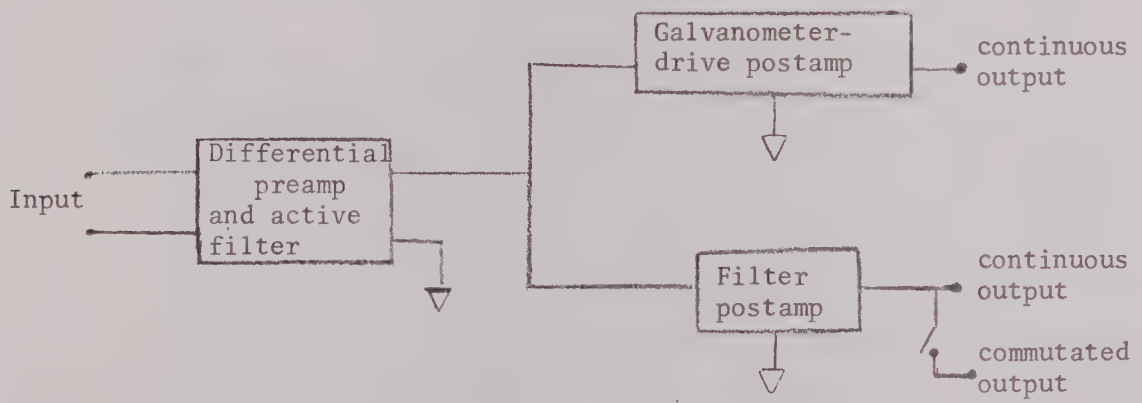
Don't readjust potentiometers other than those accessible via front panel holes.

Don't lay the amplifier on a conductive or dirty surface for checkout.

# SECTION 5
# BLOCK DIAGRAM
# EXPLANATION OF OPTIONS

A complete description of the options available in these amplifiers is given by the performance specifications and the pricing form. The purpose of this section is to present a block diagram of the amplifier as a basis for understanding the options which may be included. The block diagram below -- indeed, most of this section -- applies only to Series 60 and 70 amplifiers, for there are no post-amplifiers available in Series 50 and 55. Series 50 and 55 may, however, include output commutator switches.

A single, Series 60 or 70 amplifier package may contain as many as three, elemental amplifiers: a differential preamplifier followed by two, single-ended post-amplifiers.




With a solid-state switch located as shown, as many as three different kinds of output may be simultaneously available.

Any of the three, elemental amplifiers may be omitted for the purpose of a particular application, but the signal paths indicated in the diagram may be maintained by jumpering through the unused sections. The output switch is similarly optional.

An output stage of 100 ma capability is standard in the galvanometer driver. If the galvanometer driver is not included, the

100 ma stage may be used as the output stage of the differential preamplifier or the filter postamplifier. There is only one, 100 ma output in the package, so only one output normally may have this capability.

It is important to note that the filter postamp is not the only way of controlling bandwidth, because switchable filtering may be included as part of the differential preamp. If 6 db/octave or 12/db octave filtering in the differential preamp is satisfactory, then a filter postamp is not required. The filter postamp contributes attenuation of 12/db octave; so if, 12/db octave filtering is included in the differential preamp as well as in the filter postamp, a total rolloff rate of 24 db/octave may be obtained at the output of the active filter. Bandwidth control is ganged on a single, rotary switch no matter in which amplifier(s) the filtering takes place.

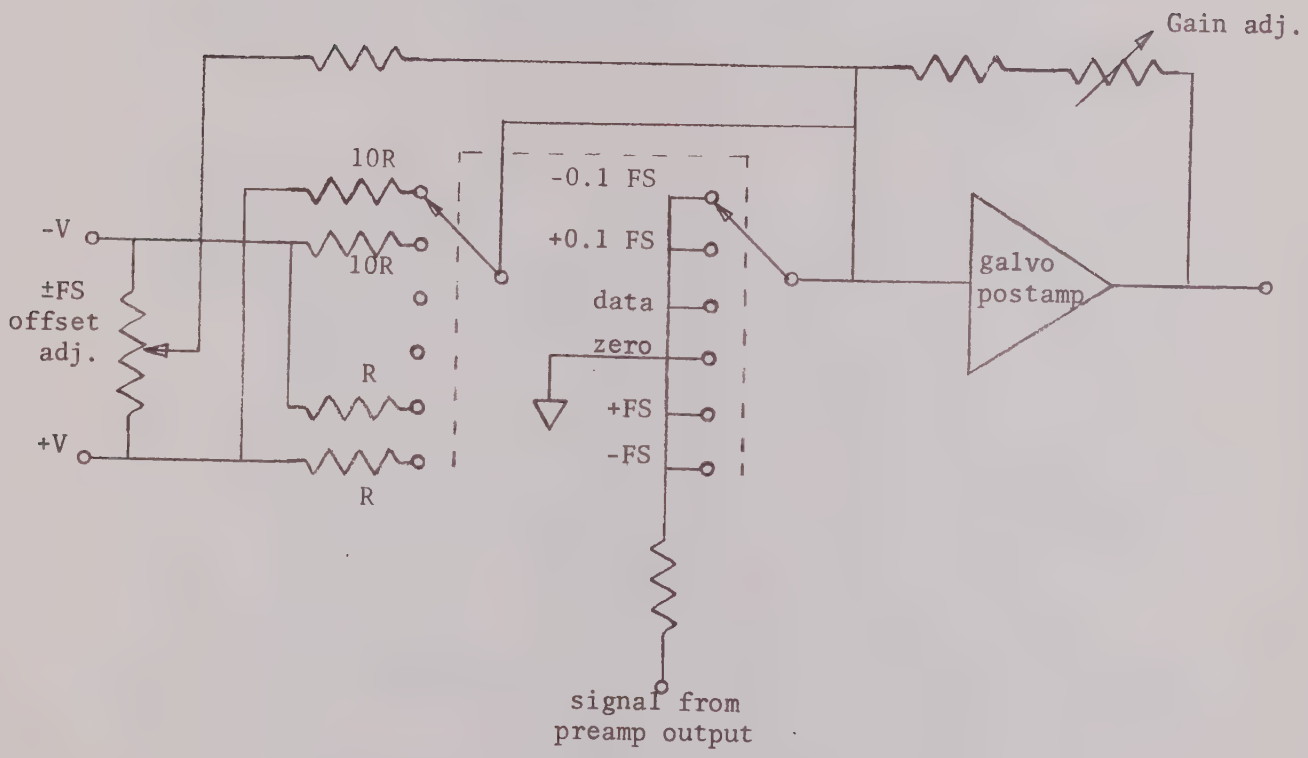
If filtering is included in the differential preamplifier, of course the bandwidth of subsequent outputs is limited accordingly. If 18 or 24 db/octave rolloff is provided using both the preamp and the postamp as filters, filter mathematics dictate that the optimum reponse characteristic (Butterworth, Bessel, etc.) is obtained only at the ultimate output from the filter postamp. The bandwidth of the preamp output in this case may differ from the bandwidth of the filter postamp by a factor of up to 1.5.

The function of common-mode rejection and the principal amplifier gain controls reside in the differential preamplifier. If an input attenuator is included, it is located before the input to the differential preamp.

For the purpose of scaling graphs in convenient units and/or suppressing offset, a self-contained calibrator and continuously-adjustable controls for offset and gain may be included in the

galvanometer driver. These capabilities are illustrated in the following simplified block diagram.

"FS" signifies full scale




OSCILLOGRAPH SCALING AND CALIBRATION CONTROLS

# SECTION 6
# ELECTRICAL CONNECTIONS

Most connections to the amplifier are made by means of the 15-pin, printed-circuit edge connector, via the quick-disconnect panel if the connector panel option is included. In addition, there are a few parts for selection by the user which mount on the circuit card. Since connections depend partly on the options included, connection information peculiar to individual orders is provided in the appendix to this manual.

The general wiring list for the 15-pin edge connector is as follows:

| connector contact no | Series 50 function | Series 55 function | Series 60 and 70 function |
|---|---|---|---|
| 1 | non-inverting data input | non-inverting input | AC or minus DC power |
| 2 | inverting data input | inverting input | AC or plus DC power |
| 3 | data input shield | input shield | power transformer shield |
| 4 | non-inverting cal. input | not used | commutator address |
| 5 | inverting cal. input | not used | commutator address |
| 6 | cal. input shield | not used | 10ma continuous output from preamp, or 100ma output |
| 7 | commutated output | commutated output | commutated output |
| 8 | continuous output | continuous output | continuous, 10ma output |
| 9 | calibration command | not used | output ground |
| 10 | not used | not used | calibration command |
| 11 | commutator address | commutator address | non-inverting cal. input |
| 12 | commutator address | commutator address | inverting cal. input |
| 13 | output ground | output ground | input guard shield |
| 14 | +25 volts DC power | +25 volts DC power | non-inverting data input |
| 15 | -25 volts DC power | -25 volts DC power | inverting data input |

When the amplifier is viewed in such an attitude that legends and nomenclature are right side up, contact no. 1 is the topmost contact and 15 is at the bottom of the contact column.

If the Series 60 or 70 amplifier contains its own DC power supply, contacts 1 and 2 are used for AC power and contact 3 is an electrostatic shield between primary and secondary of the power transformer. DC power is routed through contacts 1 and 2 and contact 3 is unused, if the amplifier does not contain its own DC power supply.

The power transformer shield should be connected in the grounding system at the point where it is most effective in preventing error due to ground loop current. If the system contains a central ground node to which separate ground conductors are returned from all components, this central node is a good place to connect the power transformer shield. Another suitable point to connect the power transformer shield might be AC power ground, provided that AC power ground is connected by some route to signal ground at the amplifier output and does not stand at a large common-mode voltage with respect to signal ground at the amplifier output. In prewired, rack-mounting holders for Series 60 and 70 amplifiers, the power transformer shield is connected to output ground contact 9 and must be disconnected from 9 if it is to be connected otherwise.

The "commutator address" inputs AND logically digital signals to turn on the output commutator switch in amplifiers containing this option. Please refer to the performance specifications in Section 1 of this manual and to the schematic diagram for details of this interface. If digital signal is applied to only one of these contacts because the AND logic is not desired, the unused contacts must be grounded.

"Output ground" should be connected to the central ground node of the analog system. In general, in the ground structure of an analog measuring system, long ground busses should be avoided and separate ground returns from each component to a central node should be used instead. Please refer to Section 9, for a more detailed explanation.

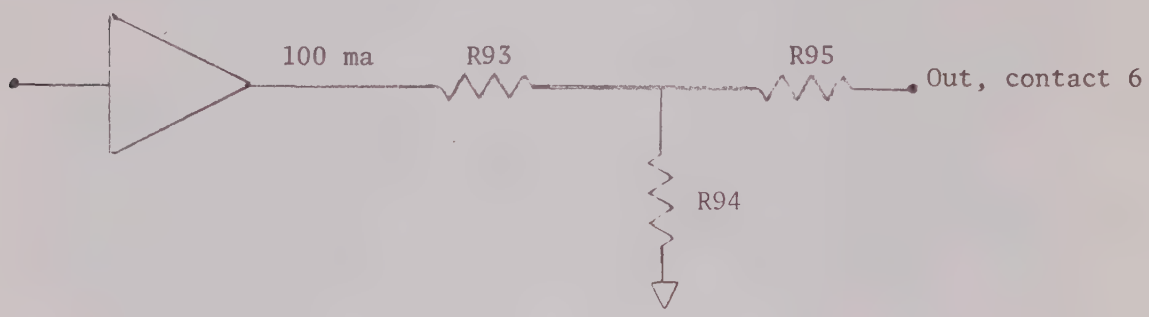
In amplifiers which include automatic calibration switching, a digital signal applied to the "calibration command" contact determines whether test data or the calibration voltage is measured. Please refer to the schematic diagram for details of this interface. A control level of +1v or less at the "calibration command" contact will cause the amplifier to be connected to the calibration input; which a control level of +2v or more will cause the amplifier to be connected to the normal data input.

The precision voltage source which supplies the calibration input signal should have as low an output impedance as possible. Ten ohms DC or less is suggested, shunted by a 1 microfarad capacitor. Twisted, shielded pair should be used for calibration signal transmission, with the shield connected to the low side or ground of the calibration source. At the amplifier end of the calibration signal cable, a terminal is provided for the shield only in the case of Series 50 amplifiers; and the shield may be left unterminated in the case of Series 60 and 70 amplifiers.

To minimize electrostatic pickup and common-mode error, the cables for both the calibration and data signals should have a foil shield to provide 100% shield coverage and a drain wire to reduce shield resistance. To minimize electromagnetic (inductive) pickup, the two input signal wires should be twisted as tightly as possible. Belden 8451 cable is recommended.

In addition to the connections on the printed-circuit edge connector, there are in the 100 ma output circuit for Series 60 and 70 several resistors which may be the user for current

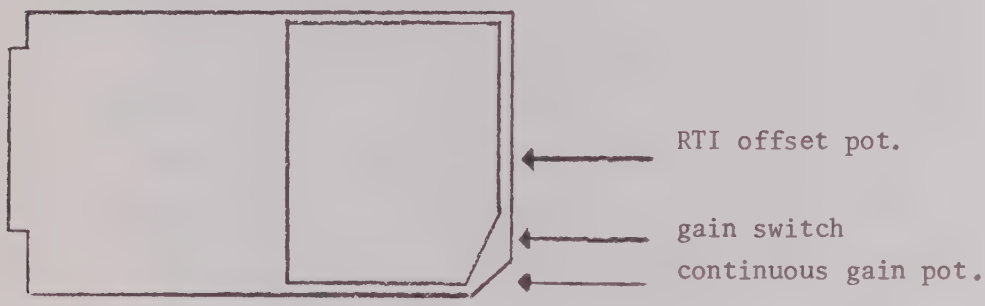
limiting or galvanometer damping. The resistors for the damping network are selected according to instructions of the galvanometer manufacturer and installed in the network:




Series 60 and 70 amplifiers are normally supplied from the factory with jumpers in the R93, R95 positions and with R94 open.

# SECTION 7
# CONTROLS

In Series 50 and 55 amplifiers, an input (RTI) offset potentiometer is included in all units. A gain switch and a potentiometer for continuous gain adjustment between switch settings are available optionally. These controls are located as shown below:




The remainder of this section concerns controls which are available only on Series 60 and 70 amplifiers. Since almost all the controls are optional, some of the controls described below will be absent from some units. (See the description of options in Section 5 of this manual.) The reader needs give attention only to the description of those controls actually present in his units. All controls are located on the front panel. When studying this part of the manual, the reader will find it helpful to have an amplifier physically before him.

## Preamp Gain Controls

The upper portion of the front panel contains the controls related to the gain of the differential preamplifier. These are (1) gain selector switch, (2) gain adjustment bypass and attenuator switch, (3) fine gain adjustment potentiometer, and (4) coarse gain adjustment potentiometer. Since these controls operate on the differential pre-amplifier, they affect all outputs.

The gain selector switch is the outer, larger knob of the upper concentric pair. If there is no gain adjustment bypass

switch, then the gain selector switch is the only knob in the upper portion of the panel. The gain or sensitivity selected is read in the window above the knob.

The gain adjustment bypass and attenuator switch is the inner, smaller knob of the upper, concentric pair. This switch controls the use of the continuous gain adjustment potentiometer(s), and switches the 1/100 attenuator in and out. When the position of this switch is marked ADJ or indicates one or both of the gain adjustment potentiometers, then the indicated potentiometer(s) is (are) operative and gain is uncalibrated. When gain is uncalibrated, the value appearing in the window is not necessarily valid. When the position of this switch is marked CAL or indicates the window which displays the setting of the gain selector switch, then gain is calibrated at the value in the window and the gain adjustment potentiometer(s) is (are) inoperative. If the attenuator is in the circuit, it is so indicated by marking the switch position x0.01. In the other positions, the attenuator is bypassed and the signal is transmitted directly to the differential preamplifier.

There may be one or two potentiometers for coarse gain adjustment, fine gain adjustment or both. When there are two potentiometers, they are labelled respectively COARSE and FINE. If there is only one gain adjustment potentiometer, it may be labelled simply ADJUST without indication as to whether it is a coarse or fine adjustment.

If the fine gain adjustment potentiometer is indicated by the inner knob, then this potentiometer may be used to adjust the gain through a range of about ±0.5% with resolution better than 0.005%.

If the coarse gain adjustment potentiometer is indicated by the gain adjustment bypass switch, then this potentiometer

may be used to increase gain above the value displayed in the window by the gain selector switch. The available range of gain adjustment is sufficient to cover fully the region between the steps of the gain selector switch. The resolution of the coarse gain adjustment is better than 0.5%.

Galvamp Controls

The middle portion of the panel contains controls for the galvanometer driver postamplifier. These controls are: (1) GAIN potentiometer, (2) OFFSET potentiometer, and (3) calibration switch -- the inner, smaller knob of the lower, concentric pair. The abbreviation "FS" on the calibration switch signifies full scale. These three controls operate on the galvanometer driver amplifier and affect its output only. Please refer to Section 5, which gives a block diagram illustrating the circuit embodiment of these controls.

The GAIN potentiometer adjusts gain of the galvanometer driver over the range stipulated at the time the amplifiers were ordered. Standard, optional gain ranges are: X0.1 to X1, X0.1 to X10, or X1 to X10. The uses of the GAIN adjustment are: (1) to scale graphic recordings in units of the original parameter, such as 10 psi or 10$^{o}$C per chart division, and/or (2) to amplify a small AC component after the OFFSET potentiometer has been used to suppress a large zero offset. To scale a graph, the gain adjustment is made to obtain the proper deflection when ±0.1 FS or ±FS signal is switched in with the calibration switch.

The OFFSET potentiometer operates on the input to the galvanometer driver and has a range of ± full scale (±10 volts) at this point. If recording of the data relative to zero voltage is desired, the OFFSET potentiometer should be adjusted with the calibration switch in the ZERO position, to establish at a convenient position on the graph the level which corresponds to zero data voltage. Alternatively, if zero data voltage is not desired

as a reference but instead the offset of the data is to be suppressed, the OFFSET potentiometer should be adjusted with the calibration switch in the DATA position to establish the offset of the data at a convenient position on the graph.

The oscillograph calibration switch is the inner, smaller knob of the lower, concentric pair. If there is no bandwidth switch, then the calibration switch is the only knob in the lower position. The DATA position is the normal position of this switch for data measurement and recording. In the ZERO position, the data input is disconnected from the galvanometer driver and its output goes to zero voltage or to whatever "zero" reference is established by the OFFSET potentiometer. In the four positions labeled ±0.1 FS and ± FS, a calibration signal of the indicated magnitude and polarity is superimposed on (added to) the data and offset inputs. (The abbreviation "FS" signifies full scale magnitude, referred to the input of the galvanometer driver.)

Input Calibration

If the oscillograph calibration option is not elected, then the inner, smaller knob of the lower, concentric switch-pair may be employed to switch the input of the differential preamplifier to a calibration source. In this case, the markings for the calibration switch are DATA, ZERO and CAL. In the DATA position, the normal input on contacts 14 and 15 is read. In the ZERO position, the amplifier input is disconnected from the outside signal sources and a short circuit is placed across it. In the CAL position, the calibration input signal on contacts 11 and 12 is read.

Bandwidth and Input Zero Controls

The lower portion of the panel contains two controls: (1) a zero potentiometer to compensate for long-term drift at the

input of the differential preamplifier, and (2) a switch for bandwidth control.

The bandwidth switch knob is the outer, larger knob of the lower, concentric pair. If there is no calibration switch, then this switch is the only knob in the lower position. The value of the selected bandwidth, in hertz, appears in the window below the knob. Bandwidth is indicated in terms of the -3 db corner frequency, unless some other bandwidth criterion was specified by the customer in the purchase contract. Depending on how the amplifiers were ordered, the bandwidth control may operate on the differential preamplifier and/or the active filter postamplifier in any of the following ways:

1. There may be no active filter postamplifier, in which case the bandwidth control operates only on the differential preamplifier, and all outputs are bandwidth-limited at the same frequency.

2. The bandwidth control may operate on the active filter postamplifier only, in which case the outputs from the galvanometer driver and directly from the differential preamplifier remain wideband regardless of the bandwidth switch setting.

3. The bandwidth control may operate on both the differential preamplifier and the active filter postamplifier. In this case, the output from the active filter postamplifier rolls off at 18 or 24 db/octave, while outputs from the galvanometer driver and directly from the differential preamplifier roll off 6 or 12 db/octave respectively; and cutoff frequency of all outputs is controlled by the bandwidth switch. The filter mechanism consists of a 1-pole or 2-pole section in the differential

preamplifier and another (2-pole) section in the active filter postamplifier. Therefore, the explicit specifications on frequency response shape (Bessel, Butterworth, etc.) and location of the -3 db frequency apply only to the active filter postamplifier output, and corresponding parameters for the preamplifier and galvanometer outputs are determined implicitly by filter mathematics.

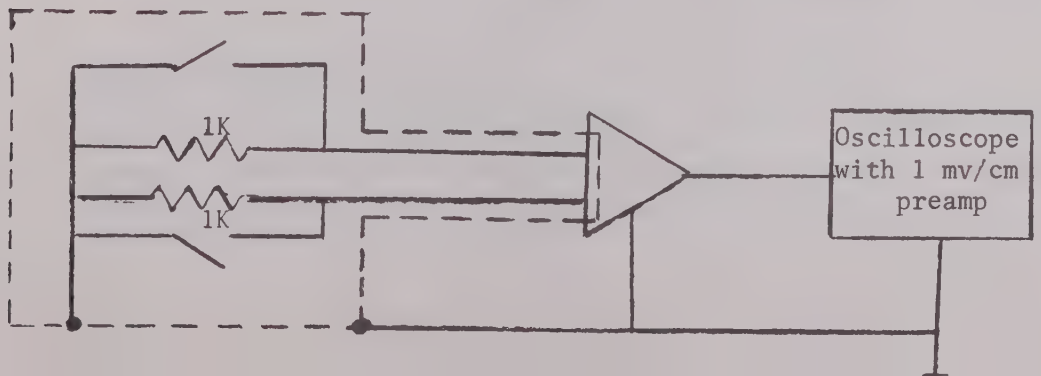
The "zero" potentiometer is used to compensate for the effect of the long-term drift at the input to the differential preamplifier. The end-to-end adjustment range of this potentiometer is 500 microvolts. While zero is being adjusted, a short circuit should be placed across the amplifier input. The preamp gain should be set at its maximum value to obtain the best possible resolution in setting zero; then the zero reference will remain the same at all values of gain.

## SECTION 8
## PERFORMANCE TESTING

Electrical performance of Series 50, 55, 60 and 70 amplifiers may be tested according to the procedures explained in this section. The complete tests described here are more exhaustive than necessary for the checking of new amplifiers for shipping damage. As an abbreviated test for this purpose, checking of the following parameters is recommended before the amplifiers are put into service: (1) noise and offset at maximum gain, with shorted input, (2) common-mode rejection at any frequency of interest, with shorted input and maximum gain, and (3) -3 db frequency at minimum gain, using about 1 volt peak-to-peak signal referred to the amplifier output. These three tests are recommended because they are easy to set up and may be conducted without any shielding of the input leads. However, this manual should be read thoroughly before the amplifiers are operated at all, with particular attention to the detailed test instructions below relating to any simplified test that is contemplated.

For tests involving low-level signals and/or large source impedances, proper sheilding of the test circuits and input leads is vital. Not only should the input cable be shielded, but the signal leads should be tightly twisted as well. A suggested shield structure is indicated by dashed lines in the test circuits described below. A further caution should be observed with respect to ground loops in the test setup.

Noise and Drift



Input errors are measured with maximum gain in the amplifier, since they overshadow the output errors at maximum gain. (Maximum gain usually is about 1000.) Output errors are measured with minimum gain in the amplifier, since input errors at minimum gain have negligible effect on the output. (Minimum gain usually is unity.) With zero resistance in the input circuit, the input errors measured are voltage offset and voltage noise. When 1K is placed in the input circuit, the increase in error is due to input current offset and input current noise. It is useful to place resistance in just one input at a time, since current offsets tend to cancel one another if the source resistance is balanced. The effects of voltage and current noise accumulate as the square root of the sum of the squares of the RMS values, since the two noise sources are gaussian.

Since noise values may be expressed in different ways, conversion factors must be kept in mind. The peak value obviously is one-half of the peak-to-peak value. The peak/RMS ratio depends on the required confidence that the stated peak value will not be exceeded, as follows:

| % of time the peak is exceeded | 10% | 1% | 0.1% | 0.01% | 0.001% |
|---|---|---|---|---|---|
| Peak/RMS ratio | 1.645 | 2.576 | 3.291 | 3.890 | 4.417 |

An instrument which determines the average, rectified value of an AC signal may be used to measure noise; and the readings may be converted to RMS values for gaussian waveform by the form factor:

$$\frac{\text{RMS value}}{\text{average, rectified value}} = 1.253$$

The form factor for a sine wave is 1.111, and many AC meters which measure the average, rectified value of a signal are calibrated to indicate readings of sinusoids on an RMS scale. Such

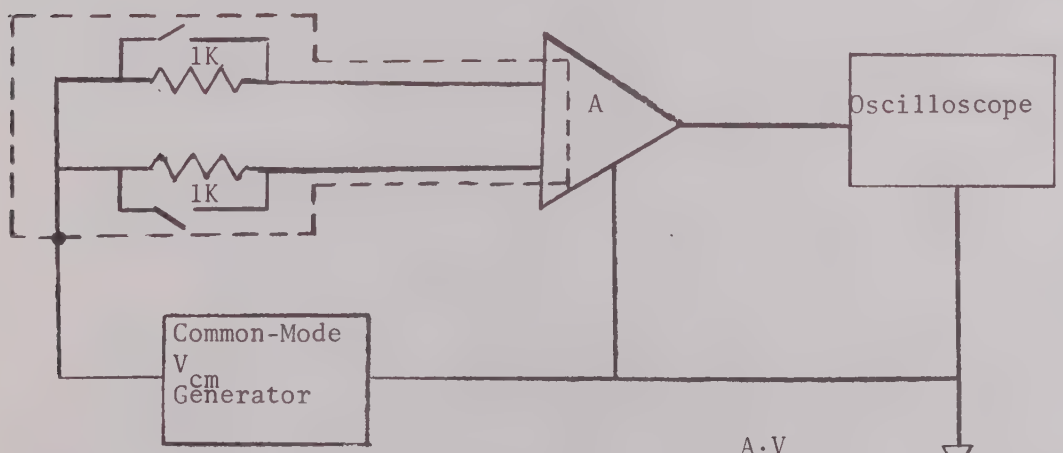
meters may be used to measure gaussian noise if the readings are converted for the change in waveform by the factor:

$$\frac{\text{RMS value of gaussian waveform}}{\text{AC meter reading}} = \frac{1.253}{1.111} = 1.128$$

The foregoing conversion factors are taken from Bennett, W.R., "Electrical Noise," pg. 44, McGraw-Hill, 1960.

Input voltage offset may be adjusted to zero by means of the screwdriver potentiometer at the bottom of the front panel. Output offset and input current offset are adjusted to near-zero at the factory and normally need not be readjusted in the field. Input noise at various bandwidths may be measured by operating the bandwidth switch, if the amplifier includes a bandwidth switch. Noise normally increases approximately in proportion to the square root of bandwidth, except at low frequencies where 1/f noise predominates.

Common-Mode Rejection




$$\text{Common-mode rejection} = \frac{A \cdot V_{cm}}{V_{out}}$$

A = differential amplifier gain

$V_{cm}$ = peak-to-peak common-mode voltage applied

$V_{out}$ = peak-to-peak voltage at the common-mode frequency, read on the oscilloscope

For Series 55 and 70 amplifiers, the common-mode rejection specifications are met with up to ±300 volts common-mode (600 volts p-p if symmetrical.) For Series 50 and 60 amplifiers, the common-mode rejection specifications are met with up to ±10 volts common mode (20 volts p-p if symmetrical.) An AC power line of 115 v nominal rms (325 volts p-p) may be used as the $V_{cm}$ generator in testing Series 55 or 70 amplifiers at the power frequency. For Series 50 or 60, and at other frequencies for Series 55 and 70, a sinusoidal, laboratory oscillator may be used to generate $V_{cm}$. The oscilloscope should have a sensitivity of 10 mv/cm or better. The bandwidth of the amplifier should be at least 2.5 times greater than the common-mode frequency generated by the oscillator.

The common-mode rejection (CMR) ratio is highest at the highest value of differential gain. CMR is specified at gain = 1000, and it is convenient to perform the measurements at this gain setting. Spot checks at lower gains may be performed quickly by switching down the gain and observing that the output error due to CMV, as displayed on the oscilloscope, remains approximately constant or decreases slightly. This indicates that CMR is proportional to gain and, therefore, output error due to a given CMV is independent of gain.

A complete check of CMR consists of a set of measurements at various frequencies under each of three conditions:

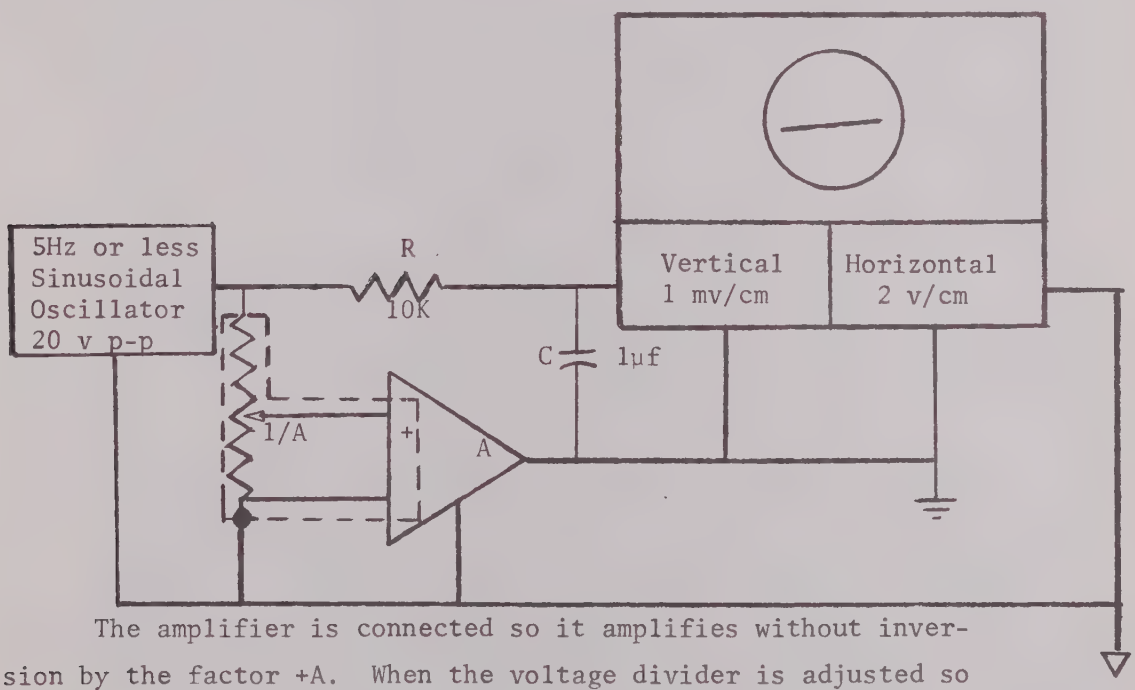
(1) Zero resistance in the input leads,
(2) 1K in one of the input leads, and
(3) 1K in the other input lead

However, if the signal is attenuated in front of the differential preamplifier, CMR is specified and should be checked only with zero resistance in the input leads.

Care should be taken to keep the CMV amplitude constant as frequency is varied, except that CMV amplitude should be reduced to 2 volts p-p at 20 kHz and above. In practical applications, common-mode voltage generally is even smaller than this at high frequencies.

Lest there be some pickup from the power line which would confuse the results, it may be advisable to avoid making a CMR measurement exactly at the power frequency. It is helpful to trigger the oscilloscope sweep by the output of the $V_{cm}$ generator to obtain a stationary waveform.

Linearity and Gain Accuracy




The amplifier is connected so it amplifies without inversion by the factor +A. When the voltage divider is adjusted so its gain is exactly equal to 1/A, perfectly linear operation of the amplifier will produce a straight, horizontal line across the face of the oscilloscope. Inclination of the line at a position other than horizontal signifies deviation of the attenuation ratio from 1/A. For example, if one end of the line is 2 mv above the middle and the other is 2 mv below, attenuation differs from the inverse of gain by 2 mv out of 10 v full scale, or

0.02%. For gain error measurement, the voltage divider must have a certified accuracy at the attenuation setting of interest at least one order of magnitude better than the specified accuracy of the amplifier gain. Also, in determining the attenuation factor, the loading effect on the attenuator of the amplifier's 100-megohm input resistance must be taken into account.

Non-linearity in the amplifier is indicated by any curvature of the line across the oscilloscope. The reference line is the best-fit straight line which intersects the oscilloscope trace at its center. Output error due to non-linearity is any displacement of the oscilloscope trace from the reference line, measured vertically in millivolts. One millivolt is 0.01% of full scale.

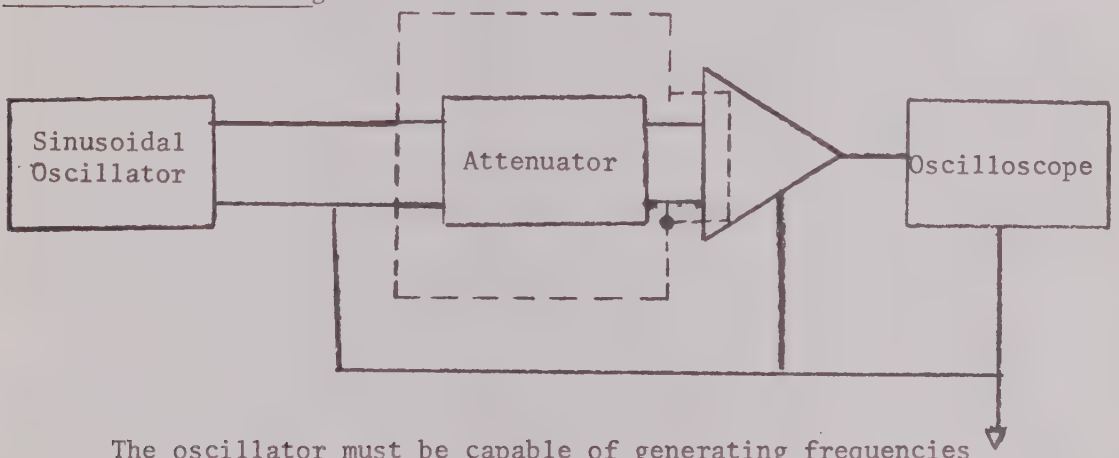
Since non-linearity is vertical deviation from the reference line, this error becomes difficult to measure if the oscilloscope trace is inclined at more than $60^{\circ}$ with respect to the horizon. Non-linearity measurement obviously would be impossible if the oscilloscope trace were vertical. Therefore, the input voltage divider should have sufficient resolution to permit adjustment to 1/A with an error no worse than 0.05%. If a step attenuator with decade switches is used, it should have at least six decades to afford satisfactory resolution at A = 1000.

The results of these test may be confused by phase shift if the frequency of the test signal is not very low in relation to amplifier bandwidth. Therefore, these test should be conducted with maximum bandwidth in the amplifier and a very slow sine wave. The ratio of bandwidth to test frequency should be greater than 10,000. Phase shift manifest itself by an elliptical trace instead of a simple line on the oscilloscope. With amplifiers having limited bandwidth -- i.e., less than 50 kHz -- a very low-frequency function generator may be used to provide the test signal.

Considering the low frequencies employed, be sure to DC-couple to the oscilloscope inputs.

If an RC filter is used to reduce noise on the oscilloscope, its corner frequency must be at least 2.5 times the signal frequency used in making the tests. R may be made up to 10 kilohms without introducing appreciable loading error. As shown in the diagram, the oscilloscope is floating with respect to amplifier ground; so a 3-to-2 adapter must be used on the power cord of the oscilloscope to avoid grounding it to the amplifier's ground through the AC line. On some oscilloscopes, it may be necessary to attenuate the horizontal input in order to obtain the desired sensitivity.

Bandwidth and Slewing




The oscillator must be capable of generating frequencies at least as high as the bandwidth of the amplifier, which may be as much as 100 kHz. The attenuator is convenient for reducing the input signal as amplifier gain is increased. To obtain a stationary waveform, it is helpful to trigger the oscilloscope sweep by the output of the oscillator.

The -3 db frequency or small-signal bandwidth is determined using a test signal of small enough amplitude to avoid slew limiting which affects high-frequency response to large-amplitude signals. (A separate test to determine slewing characteristics is described later.) At gains of 3 or more, the test signal may be no greater than 10 volts peak-to-peak at the amplifier output. At gains less than 3, the pertinent limitation is the input slewing limit, which dictates that the test signal be no greater than 3.2

volts peak-to-peak at the amplifier input.

The procedure for determining small-signal bandwidth is to increase the signal frequency, keeping constant input amplitude, until the frequency is reached where the signal at the amplifier output is attenuated by 3 db. Since oscillators do not necessarily maintain constant amplitude as the frequency is varied, it is advisable to monitor the oscillator's output as well as the amplifier's output with the oscilloscope.

Nominal bandwidth is the -3 db frequency for most amplifiers. However, other criteria for bandwidth indication may be adopted on special order, so contract specifications should be consulted in case any anomaly is found in testing bandwidth. With regard to multi-pole filters, it must be kept in mind that the -3 db frequency is not necessarily the same as the natural frequency or asymptotic corner frequency. Also, 3-pole and 4-pole filters are constructed in two sections; and frequency-response characteristics usually are specified only for the final output since this implicitly determines the characteristics of both sections. The bandwidth of the differential preamplifier section of a 3-pole or 4-pole filter normally may differ from the bandwidth of the final output by a factor of up to 1.5. Please refer to Section 5 for additional details regarding multipole filters.

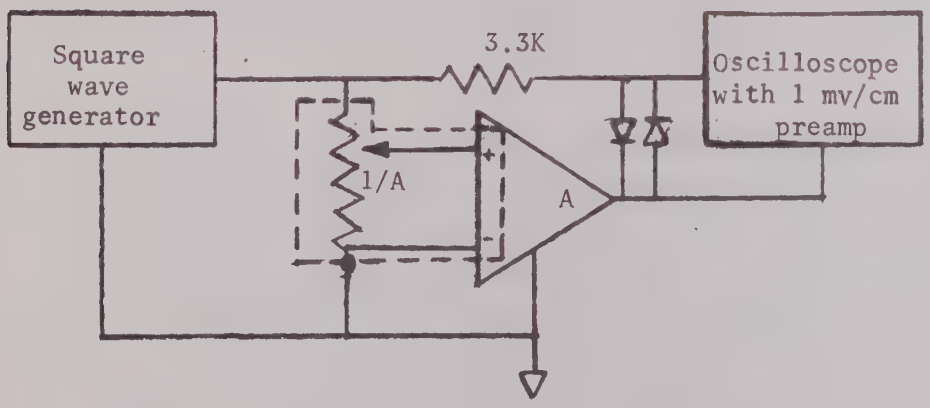
The slewing limit is most easily determined by driving the amplifier to an output of 20 volts peak-to-peak and increasing the signal frequency until the output sine wave begins to distort. The slewing limit then is the maximum slope of the 20-volt, p-p signal at the frequency f (in hertz) on the verge of distortion, which may be calculated

$$\frac{dv}{dt} = 20\pi f \text{ volts per second}$$

The slewing limit measured at unity gain is the input slewing limit, and the slewing limit measured at a gain of 3 or greater is the output slewing limit.

Another method of determining the slewing limit is to look for rectification as the amplifier is driven to ± fullscale excursions with a sine wave of increasing frequency. This is accomplished by use of a low-pass filter connected ahead of the oscilloscope to attenuate the test frequency and permit the use of greater sensitivity in the oscilloscope. As the signal frequency is increased beyond the slewing limit, a shift in the DC level may be observed at the amplifier output. At high frequencies, a DC level shift of 10 millivolts may be considered an error of sufficient significance to serve as a criterion of slew-limiting. The frequency at which slew-limiting appears according to this test may be somewhat different from the frequency determined according to the distortion test, but the published slewing specification should be met according to either test method.

Settling Time




The amplifier is connected so it amplifies without inversion by the factor +A. When the voltage divider is adjusted so its gain is exactly equal to 1/A, perfectly linear operation of the amplifier would produce a null across the oscilloscope. Deviation of the attenuation from 1/A will permit a steady-state square wave on the oscilloscope, which is tolerable as long as its amplitude is less than the forward breakdown voltage of the clamp diodes. The oscilloscope should be synchronized by connecting

amplifier ground to its external trigger, and adjusted to display the transient error just after the rise (or fall) of the test signal. Notice that the oscilloscope must be floating with respect to amplifier ground; so a 3-to-2 adapter must be used on the power cord of the oscilloscope to avoid grounding it to the amplifier's ground through the AC line.

To meet the settling times stated in the published specifications, the amplifier must have 100 kHz bandwidth capability. For amplifier bandwidths of 16 kHz or less, a properly functioning amplifier will settle according to the theoretical response of the filter employed, so empirical data in this region ordinarily are not needed. At high gain and bandwidth, the noise on the oscilloscope may be larger than the residual settling error which is sought, but any attempt to filter this noise will tend to retard settling.

Diode clamps are used across the input to the oscilloscope to limit the overdrive voltage, but still the oscilloscope must be able to recover from overdrive (to a residual error less than 1 millivolt) within 5 microseconds. Suitable 'scope preamps are: Hewlett-Packard type 1803A or Tektronix type W.

Performance of the amplifiers is specified for response to a step change of 10 volts referred to the output, so a 10-volt (peak-to-peak) square wave may be used to check this specification. The purpose of the 3.3K resistor is to limit the transient load currents out of the amplifier and the square wave generator.

# SECTION 9
# SHIELDING AND GROUNDING

High-impedance, differential amplifiers, such as described in this manual, enable accurate, electrical measurements from environments where ground-loop currents are large and electrical or magnetic interference sources abound. To be sure of obtaining this advantage, the user must employ proper techniques in system wiring, namely:

1. Twisted, shielded cable must be used to connect the amplifier to its signal source, and the shield must be operated at the same AC common-mode voltage as the signal source.

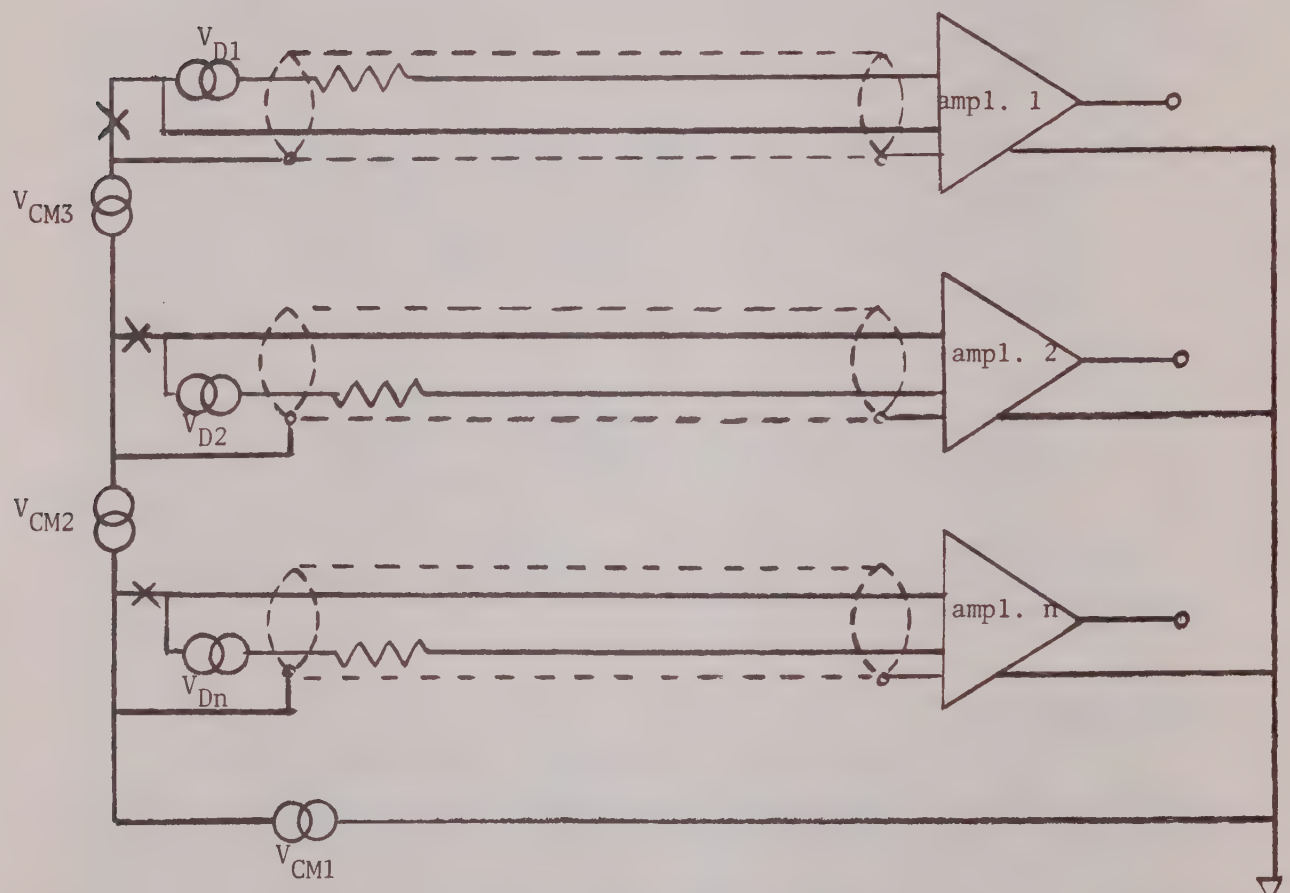
2. Wiring and grounding of the amplifier outputs must be such that ground loop or interference problems are not introduced on the output side of the amplifiers.

Some of the details involved in implementing these principles are discussed below.

## Input Shielding

The effects of ground loop currents and interference sources are indicated by common-mode generators labelled $V_{CM}$ in the diagram below. The differential signals desired are labelled $V_D$. The resistors represent cable resistance and the source resistance of the differential signals, which may be unbalanced as shown. The shield is made to operate at the same AC common-mode voltage as the signal source by grounding it at the nearest possible proximity to the $V_D$ source device. It may also be desirable to ground at the same point that side of the $V_D$ source device which has the lower impedance coupling it to possible sources of electrical interference -- but only if grounding the $V_D$ source device would not impair its function or that of any circuits associated with it. As long as the shield is grounded at the $V_D$ signal source, the $V_D$ source device itself may be left to float as indi-

cated by crosses in the diagram below showing where connections would be absent in this case. If the $V_D$ source device is a transducer with a cable connecting it to remote conditioning equipment, the shields of both the transducer-conditioning cable and the amplifier input cable should be grounded together.

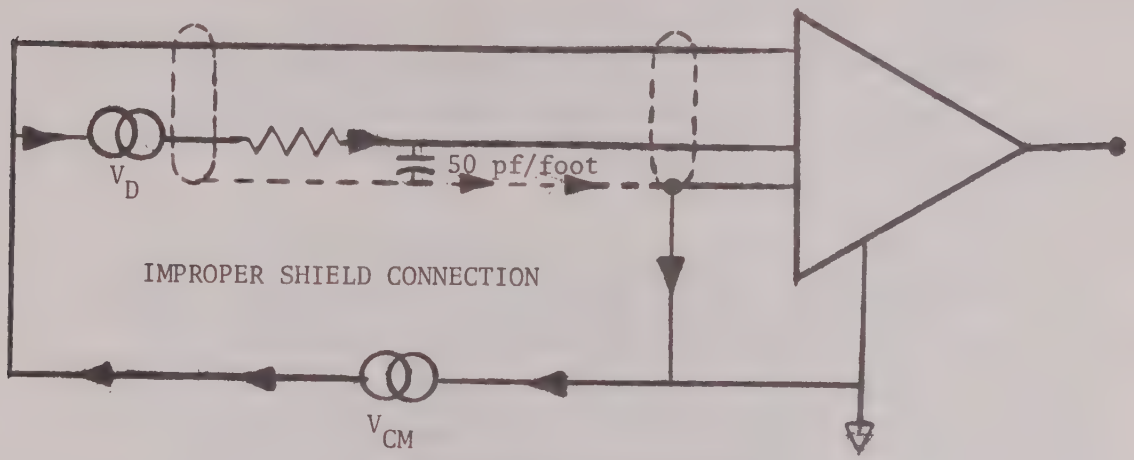



PROPER SHIELD CONNECTION

amplifier ground

With the shields connected as shown, the $V_{CM}$ voltages appear as common-mode inputs to the amplifiers and are rejected. Only the differential signals $V_D$ are measured. A serious error sometimes made is to ground the shields at the amplifier instead of grounding them at the signal source. The capacitance from the shield to the signal conductors is typically 50 pf per foot of cable; so grounding

a shield at the amplifier causes AC error current to flow from the $V_{CM}$ sources through the differential signal circuit and back to amplifier ground through the shield as follows:




The measurement error introduced by this connection is the voltage drop across the impedance of the differential signal circuit caused by error current around the loop indicated by arrow heads. For example, the error would be about 190 millivolts in the case of a 1000-foot cable, 1 kilohm in series with $V_D$, and $V_{CM}$ of 10 volts peak at 60 Hz.

In cases where it is necessary that the $V_D$ signal source must float (i.e., be ungrounded), the best connection of the shield is not always obvious and may have to be determined experimentally. One way to dispose of the shield would be to connect it to whatever mass of conductive material is nearest the signal source, even though the nearest mass is not returned to earth ground. Another choice of shield connection, which would be the most logical if there is no conductive material near enough to affect fields around the signal source, would be the nearest point that does return to earth ground. An improvement on these choices would be to connect the shield to the nearest mass of conductive material, and then if necessary make a connection of that mass to earth ground. It is never advisable to leave the shield unterminated at the signal source end. If the $V_D$ signal source is sufficiently isolated from other conductive materials, then the AC common-mode voltage of any point chosen for shield

connection will become the AC common-mode voltage of the signal source -- which fulfills the fundamental objective of shield connection.

Of course it is always preferable that the shield enclose the $V_D$ source device itself as well as the amplifier input cable, especially if the $V_D$ source is a high-impedance device.

In Series 50 and 60 amplifiers, common-mode voltages are rejected only if they are no greater than ±10 volts peak. Excessive common-mode voltage may manifest itself unexpectedly by apparent cross-talk between channels, DC offset, high-frequency oscillations, or excessive noise at the power line frequency. Should any of these troubles appear, the common-mode voltage should be checked by connecting an oscilloscope between the amplifier's input shield and its output ground.

Inasmuch as the amplifier's impedance from shield to ground is greater than the input impedance of an oscilloscope, connection of the oscilloscope at this point may attenuate an excessive common-mode voltage to a level which appears on the oscilloscope to be less than 10 volts peak. If so, the symptoms of excessive common-mode voltage should disappear when the oscilloscope is thus connected.

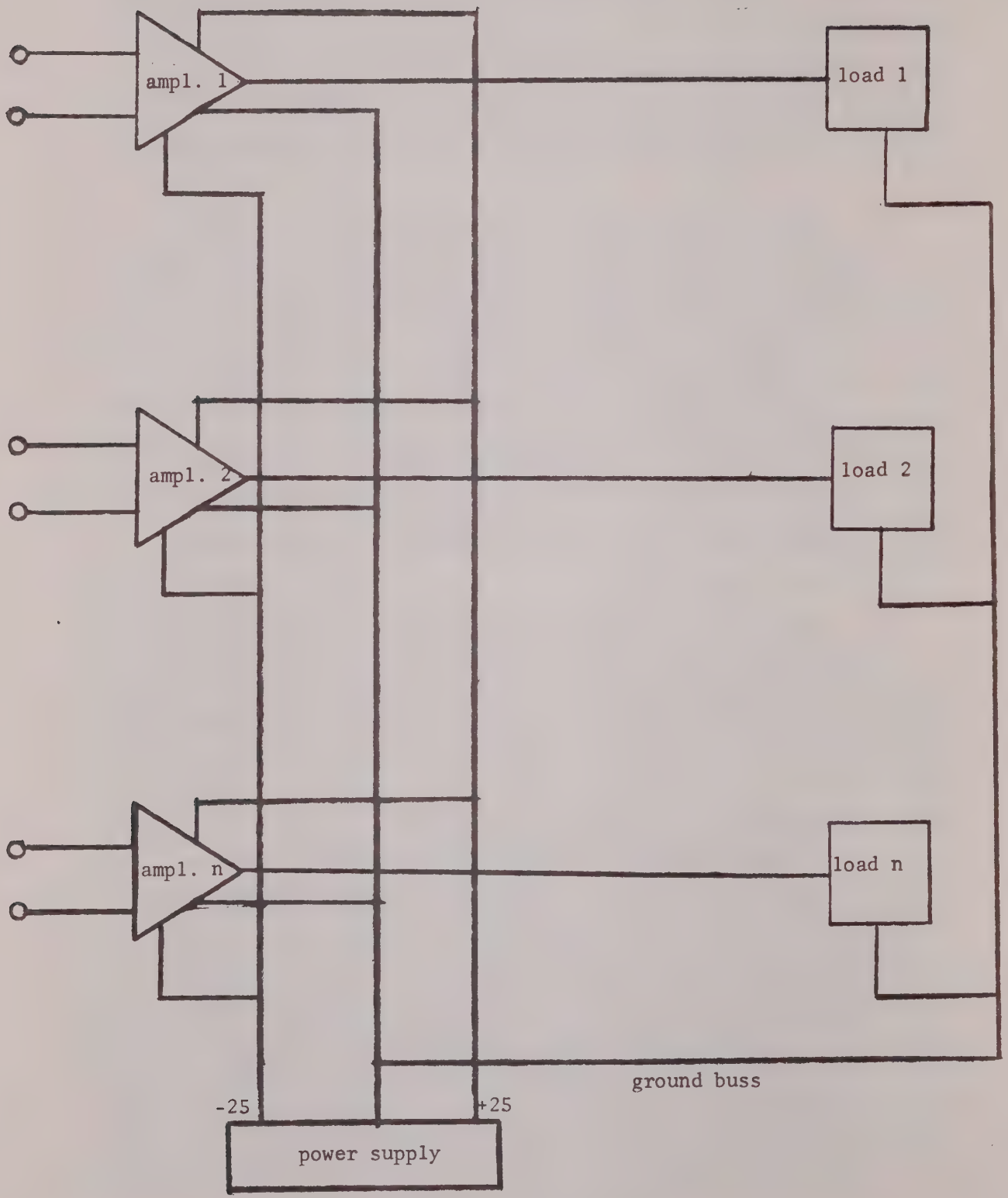
An alternate point of shield connection or re-routing of signal cables to avoid interference sources may be a solution to difficulty with excessive common-mode voltage on Series 50 and 60 amplifiers. If not, then the common-mode voltage may be attenuated if it originates from a high-impedance source, by placing a 1 megohm or smaller resistor between the input shield and output ground contacts on the amplifier connector. Successively smaller resistors, as small as 47 kilohms, may be tried until success is obtained. Once a resistor value for this purpose is determined, it may be installed on the printed circuit card in the place of the standard, 47-megohm resistor: R2 in Series 50 or R3 in Series 60.

Output Wiring

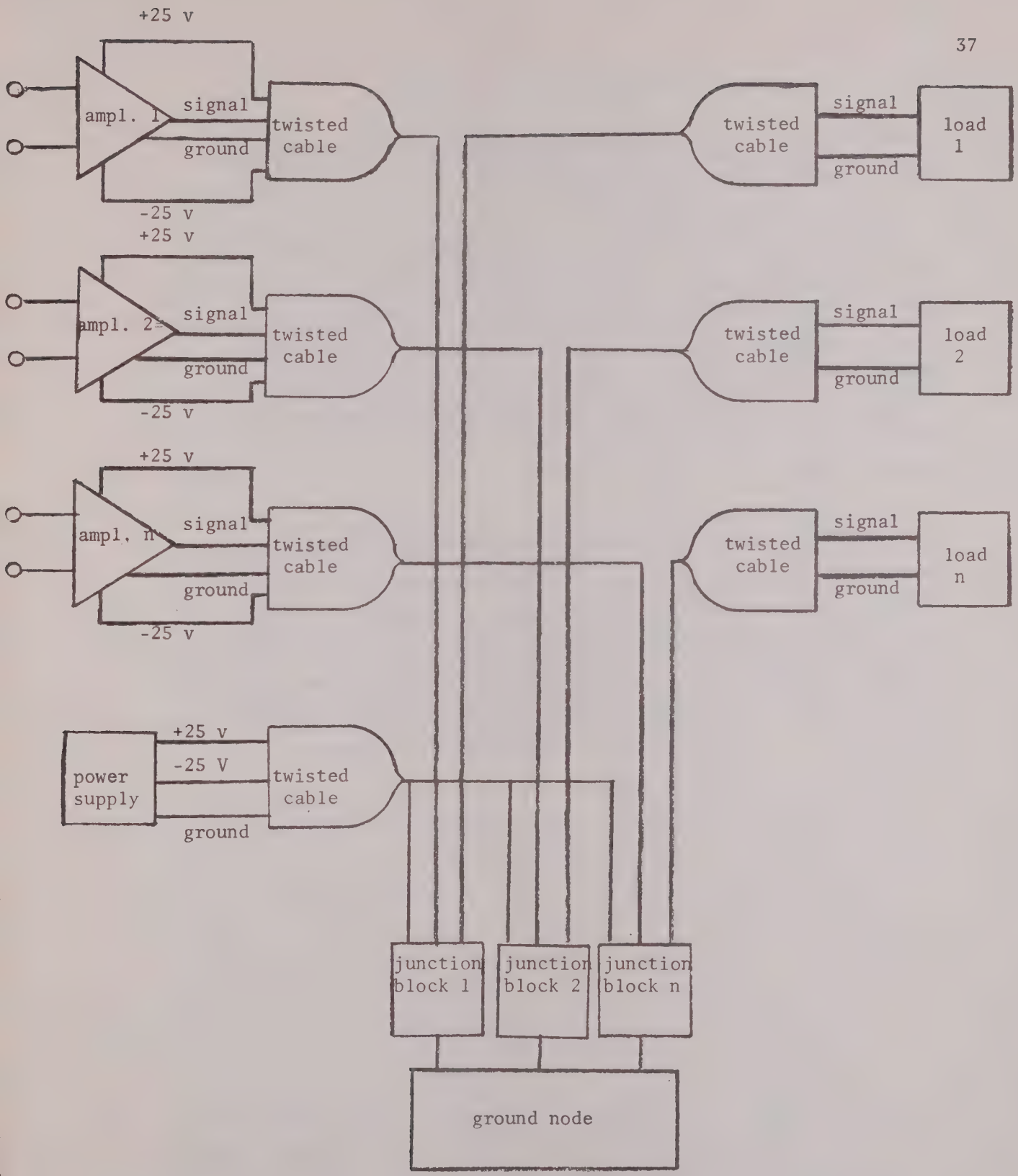
The differential amplifier transfers the desired signal into a common-ground (i.e., single-ended) environment from an environment in which ground loops and common-mode voltages are permitted. Unless a second echelon of isolation hardware is to be used, the wiring of the outputs in the common-ground environment must be designed so ground loops and interference problems in this environment will not exist.

The symptoms of improper output wiring tend to be mysterious and sometimes difficult to distinguish from the symptoms of faulty input shielding, excessive common-mode voltage or malfunction of an amplifier itself. Oscillations, offsets or 60-hertz pickup may result from improper output wiring. Usually there is interaction between channels -- i.e., the behavior of a channel under observation is altered by removing an amplifier from a different channel -- but this symptom does not rule out the possibility that the trouble may originate from a different cause.

The key to good grounding is to minimize the resistance and the physical dimensions of the ground structure. The key to stability and immunity from interference is to minimize inductance in the signal cables. To achieve these objectives, long busses must not be used for interconnection of common terminals. Instead, a point ground should be approximated by use of a solid block or short bar of copper; and twisted cables should be used in such a way that the net current of all conductors twisted together in the same cable is near zero. These principles are illustrated by the diagrams of proper and improper output wiring. The junction blocks should be located in proximity to the ground node so no more than a few inches of interconnecting wire is needed outside the twisted cables. If several units are cascaded in series in the common-ground environment, twisted cables should be returned from the input and output of each to the junction-block/ground-node




IMPROPER OUTPUT WIRING




PROPER OUTPUT WIRING

structure, where short interconnections should be made instead of running common busses along cascaded units.

The diagrams herewith illustrate the connection of amplifiers with shared power supply. If each amplifier contains its own power supply, the power-supply wiring would be simply omitted from the diagrams. It is permissible to buss AC power to amplifiers with integral DC power supplies, because isolation from signal ground is provided by the power transformers. A single connection to the signal ground node should be made from some convenient point in the AC power system.

The output wiring rules given here represent conservative design practice which becomes increasingly important as the system increases in physical size, but violation of them does not necessarily spell calamity in small systems. A degree of simplicity or convenience sometimes may be obtained with impunity by employing practices which are disparaged above, but such a design should be adopted only in full awareness of the possibility of trouble.

# SECTION 10

## MAINTENANCE and TROUBLESHOOTING

If malfunction of the amplifiers is suspected, it should be tested under controlled conditions according to the procedures described in Section 8. In failure of the amplifier is confirmed, it should be returned to the factory for repair. If the amplifier operated properly under controlled conditions but appears to malfunction when installed in a system, then improper grounding, wiring or shielding should be suspected and the techniques employed should be reviewed in light of the advice given in Section 9. Please consult Newport Laboratories in case of persistent application difficulties.

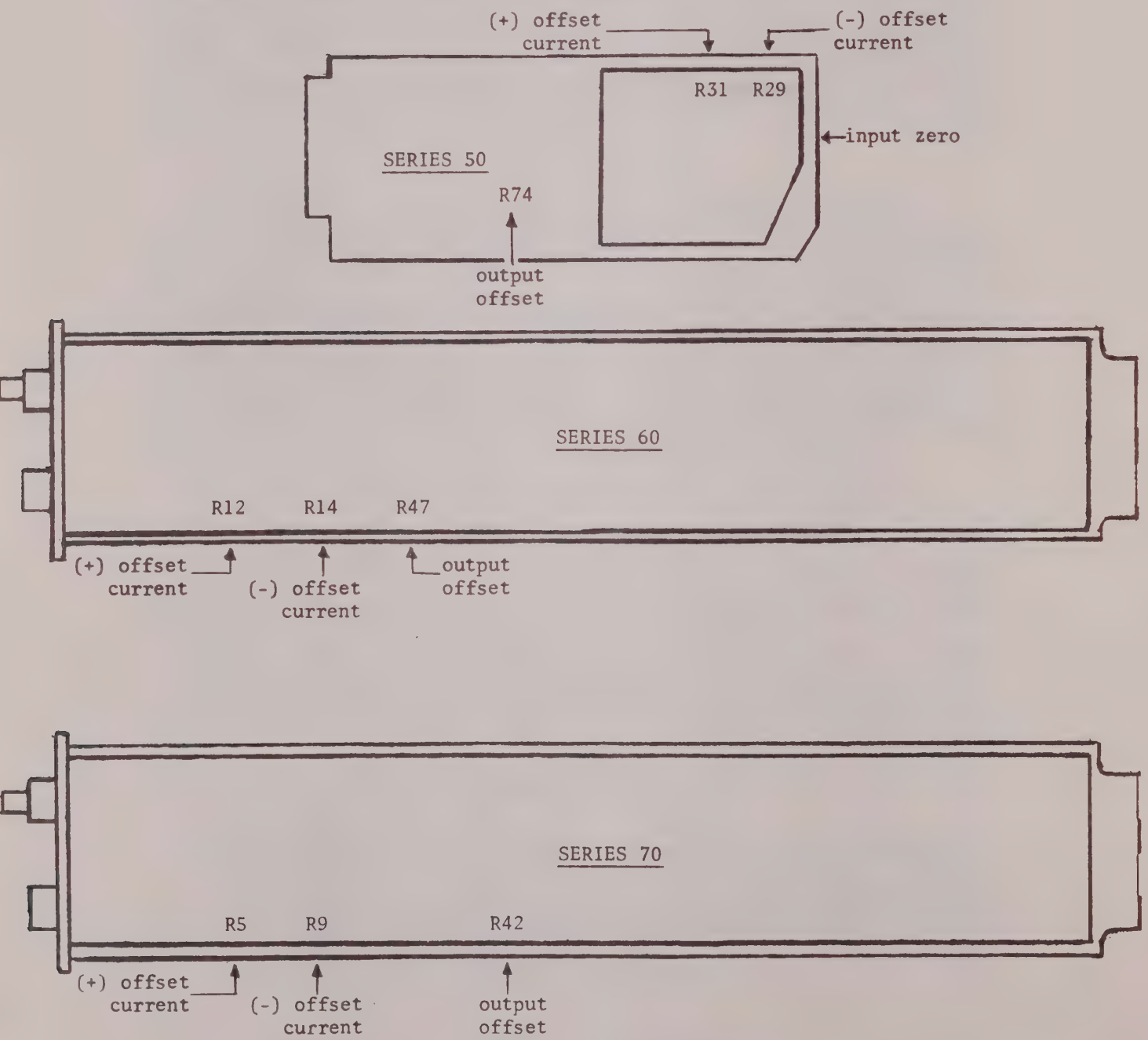
To correct for long-term, input drift, there is a potentiometer accessible from the front while the amplifiers are in normal use. This input zero potentiometer is at the lower, lefthand corner of the front panel in Series 60 and 70 amplifiers. In Series 50 and 55 amplifiers (which have no front panels), the input zero potentiometer is accessible through a hole in the front edge of the shield cover, when the amplifiers are plugged into a rack adapter.

In addition to the input zero adjustment, there are three maintenance adjustments which may require attention in the course of initial installation or after an extended period of use, but not as a regular operating procedure. These are two potentiometers for adjustment of input offset current -- one for each of the signal inputs -- and one potentiometer for adjustment of output offset. The type of potentiometer (in parantheses) and reference designations for these adjustments are tabulated as follows:

| | Series 50 | Series 60 | Series 70 |
|---|---|---|---|
| offset current non-inverting input | R31 (Amperex) | R12 (Amperex) | R5 (Amperex) |
| offset current inverting input | R29 (Amperex) | R14 (Amperex) | R9 (Amperex) |
| output offset | R74 (Amperex) | R47 (Amperex) | R42 (79P) |

The "Amperex" potentiometer used in these amplifiers approximates a disk about 0.3 inch in diameter, and stands on its edge. The 79P is a rectangular, encapsulated trimmer about 0.8 inch long.

A general indication of location for these maintenance adjustments is given in the following diagrams:




See also the detailed assembly drawing in the appendix to verify location of the adjustments.

To obtain access to the offset current and output offset potentiometers, the amplifier must be removed from its rack adapter or single-amplifier case, and may be set up on a test bench with wiring to a printed-circuit edge connector. It is important to be sure AC power is turned off while the P.C. edge connector is being plugged onto or removed from the amplifier. Be careful also that the P.C. edge connector is not reversed incorrectly end-for-end. In some Series 60 and 70 amplifiers, it is necessary to remove the steel, U-channel cover to obtain access to the potentiometers; in others, there are access holes punched in the cover.

To adjust offset current, set up the amplifier with maximum gain in the test circuit shown on page 21. The offset current pot may be adjusted so there is no change in output as the source resistance is switched from zero to 1K in the input lead associated with the potentiometer under adjustment.

RTO (output) offset adjustment

1. Allow the amplifier to warm up for 30 minutes or more, with its cover on.

2. Turn the amplifier's switch to minimum gain (usually 1).

3. If the amplifier has a potentiometer for continuous, coarse gain adjustment, turn it clockwise to maximum. This potentiometer is labelled on the front panel either COARSE or, if there is only one continuous adjustment, ADJUST.

4. The preamplifier RTO offset potentiometer is R74 in Series 50, R47 in Series 60 and R42 in Series 70. In either Series 60 or Series 70, the zero potentiometer for the active filter post-amplifier is R121. The zero potentiometer for the galvanometer-drive post-amplifier is either R102 located internally or R78 located on the front panel. Please refer to the assembly drawing for location of these potentiometers. In Series 60 or 70 amplifiers, all internal potentiometers (those not accessible through the front panel)

are located along the lower edge of the printed-circuit card. The procedure for adjustment of output offset varies according to the options included in the amplifiers. Check the applicability of 4.1, 4.2, and 4.3, and use whichever procedure is appropriate.

4.1 Use this procedure for Series 60 or 70 amplifiers which have either or both post-amplifiers and a bypass switch to disconnect the continuous, coarse gain adjustment.

4.1.1 While switching the continuous, coarse gain adjustment in and out with the bypass switch, adjust the preamp RTO offset potentiometer so there is no change in the output as the bypass switch is operated. In dual-output amplifiers, either output may be measured for the purpose of this step.

4.1.2 If the amplifier has an active-filter post-amplifier, set its output (contact 8) to zero by adjusting potentiometer R121.

4.1.3 If the amplifier has a galvanometer-drive post-amplifier, set its output (contact 6) to zero by adjusting potentiometer R102 or R78.

4.2 Use this procedure for Series 60 or 70 amplifiers with two post-amplifiers but without gain-adjustment bypass switch.

4.2.1 Measure the output of the active-filter post-amplifier (contact 8) and set it to zero by adjusting the preamplifier RTO offset potentiometer (R47 in Series 60 or R42 in Series 70).

4.2.2 Turn the continuous, coarse gain adjustment counterclockwise all the way to its minimum value.

4.2.3 Again measure the output from contact 8, and multiply it by a factor depending on the switch step sequence of the amplifier, as follows:

| Gain switch steps | Factor |
|---|---|
| 1,10,100... | -0.1 |
| 1,3,10... | -0.4 |
| 1,2,5,10... | -0.6 |

4.2.4 Using potentiometer R121, adjust the output (Contact 8) to the value obtained by the calculation of 4.2.3. This reverses the polarity of the output and reduces its absolute value.

4.2.5 Still measuring the output of Contact 8, and, using potentiometer R47 in Series 60 or R42 in Series 70 (the preamplifier RTO offset potentiometer), set the output to zero.

4.2.6 Turn the continuous, coarse gain adjustment clockwise to its maximum setting.

4.2.7 Measure the output offset on Contact 8. If it is excessive, repeat steps 4.2.1 through 4.2.7.

4.2.8 Set the offset of the galvanometer-drive post-amplifier (Contact 6) so it is the same as Contact 8, by adjusting potentiometer R102 or R78.

4.3 Use this procedure for Series 60 or 70 amplifiers with one post-amplifier and without a gain-adjustment bypass switch.

4.3.1 Measure the output direct from the differential preamplifier, node Z on the schematic diagrams. This may be either contact 6 or contact 8 depending on the options included. Set this output to zero using the preamplifier RTO offset potentiometer, R47 in Series 60 or R42 in Series 70.

4.3.2 Measure the other output, the one from the post-amplifier. Set it to zero using R102 or R78 if it is the galvanometer-drive post-amplifier. Or use potentiometer R121 if the post-amplifier is the active filter.

4.4 Use this procedure for Series 50, 60 or 70 amplifiers without any post-amplifier.

4.4.1 If the amplifier has a gain-adjustment bypass switch, turn it to place the continuous, coarse gain adjustment in the circuit.

4.4.2 Zero the output using the preamplifier RTO offset potentiometer:

| Series 50 | Series 60 | Series 70 |
|---|---|---|
| R74 | R47 | R42 |

## SPECIAL CHARACTERISTICS

These Model 60-1 amplifiers contain switchable gain and fixed bandwidth. The input is fuse-protected against over-voltage up to ±300 volts common or normal mode. Each unit contains an integral power supply for 115V RMS operation.

Gain is set with fixed steps and vernier controls. The steps are 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 and 2000, calibrated within 0.1%. Gain is calibrated at the nominal value when the gain adjustment bypass switch indicates the window where the gain setting is displayed. The gain adjustment bypass switch is the inner knob of the concentric gain control. Continuous gain adjustment becomes operative when selected by gain adjustment switch. The range of the continuous gain adjustment is sufficient to increase gain up to 2.5 times relative to the setting displayed in the window.

Additionally, the gain may be altered 100:1 by engaging switchable input attenuators.

Bandwidth is fixed at 10 Hz with 2-pole Butterworth response.

Options included with the 60-1 amplifier are A17, Bal0, C1, D, F, H5 and P1.

| CIRCUIT NO. | ITEM NO. | DESCRIPTION | PART NO. REV | MFR CODE | QTY |
|---|---|---|---|---|---|
| REF DWG. | | Amplifier Assy. Drawing | 01092 | | REF |
| " | " | Amplifier Schematic | 01093-01 | | " |
| " | " | Power Supply Schematic | 01093-09 | | " |
| " | " | Ampl. Options Schematic | 01093-01 | | " |
| | | | | | |
| Option 60-1, | F | Basic Amplifier Assembly | 01091 | | 1 |
| " | F1 | Power Supply | 01302-01 | | 1 |
| " | H5-1 | Rm Network, 1-2.5 Gain | 01155-02 | | 1 |
| " | A17 | Gm Network 1,2,5,10,20,50; 100,200,1K,2K | 01177-01 | | 1 |
| " | Bal0,C1 | 2 Pole, But. Filter, 10 Hz | 01157-10 | | 1 |
| | D | Input Attenuator | 01174-01 | | 1 |
| | | Schematic, Input Attenuator | 01093-10 | | Ref |
| | | | | | |
| | | Jumper J6-A to Pin 8 Side of R96 & C59 | | | |
| | | Amplifier Mechanical | 01591 | | |
| | | Panel, Front | 01090-01 | | REF |
| | | Silkscreened Panel | 01200-28 | | 1 |
| | | | | | |
| | | Knob, Control (dual) | 9001202 | | 1 |
| | | Dial Wheel, Gm | 01196-04 | | 1 |
| | | | | | |
| | | Detent Assy, Gm (Pos 1-11) | 01216 | | 1 |
| | | Detent Assy, Rm (Pos 2-5) | 01218 | | 1 |
| | | | | | |
| | | | | | |

| REV | E.O. NO. | BY/CHK | DATE |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

JOB # 1078

BY

CHK

APPD

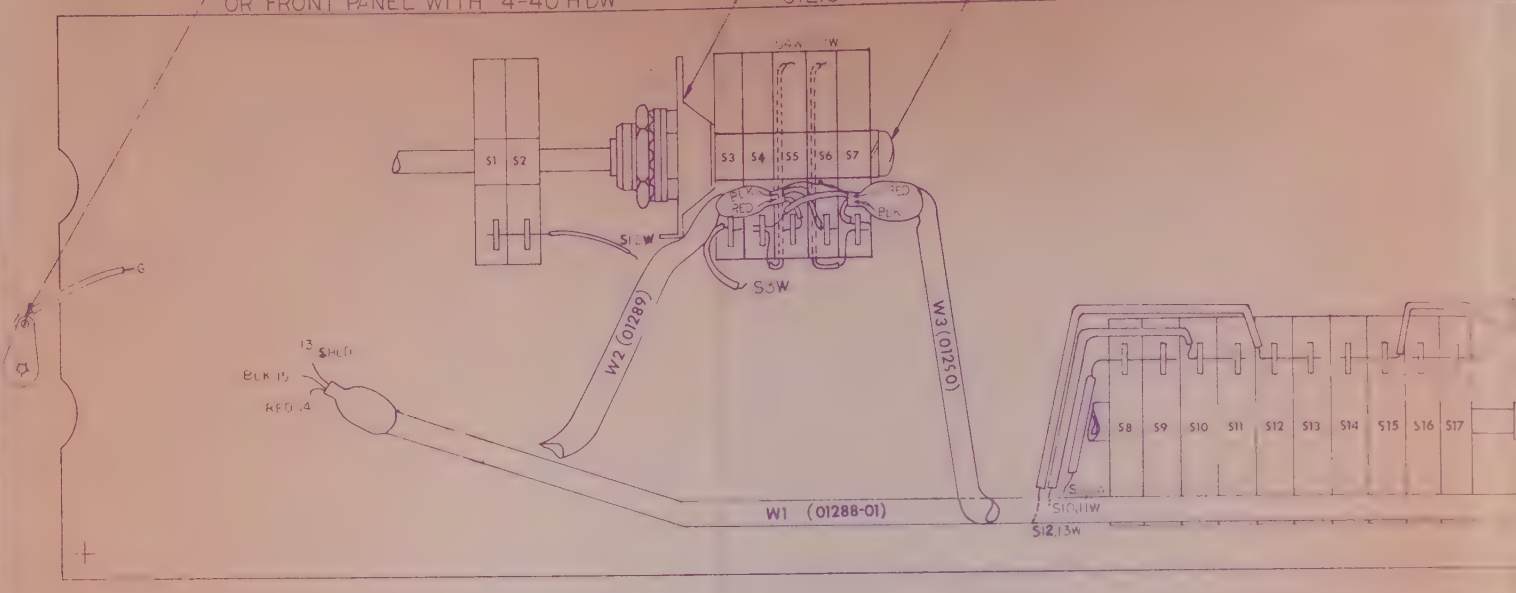
DATE 2-5-68

NEWPORT LABORATORIES INC.
630 E. YOUNG ST. SANTA ANA, CALIF., 92705

TITLE: SERIES 60 AMPLIFIER TOP ASSEMBLY

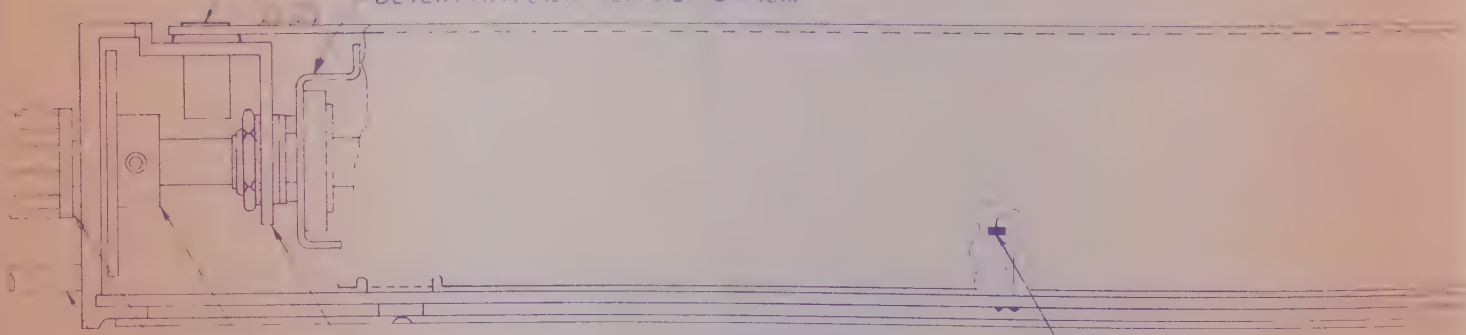
PART LIST NO. 01450-23

MODEL 60-1 | ASSY 01092 | SHEET 1 OF 1



INSTALL AFTER CLEANING

DETENT ASSY 01217 FOR 01218 BOTTOM



FRONT PANEL 01090

KNOB (3) (7) (2)

DIAL WHEEL 01196

CATHODE ON TOP

| SYMBOL | REPRESENTS |
|---|---|
| | CR-DIODE |
| | R - RESISTOR ALL SIZES |
| | Q-TRANSISTOR |
| | Q-TRANSISTOR |
| | WIRE TERMINATION |

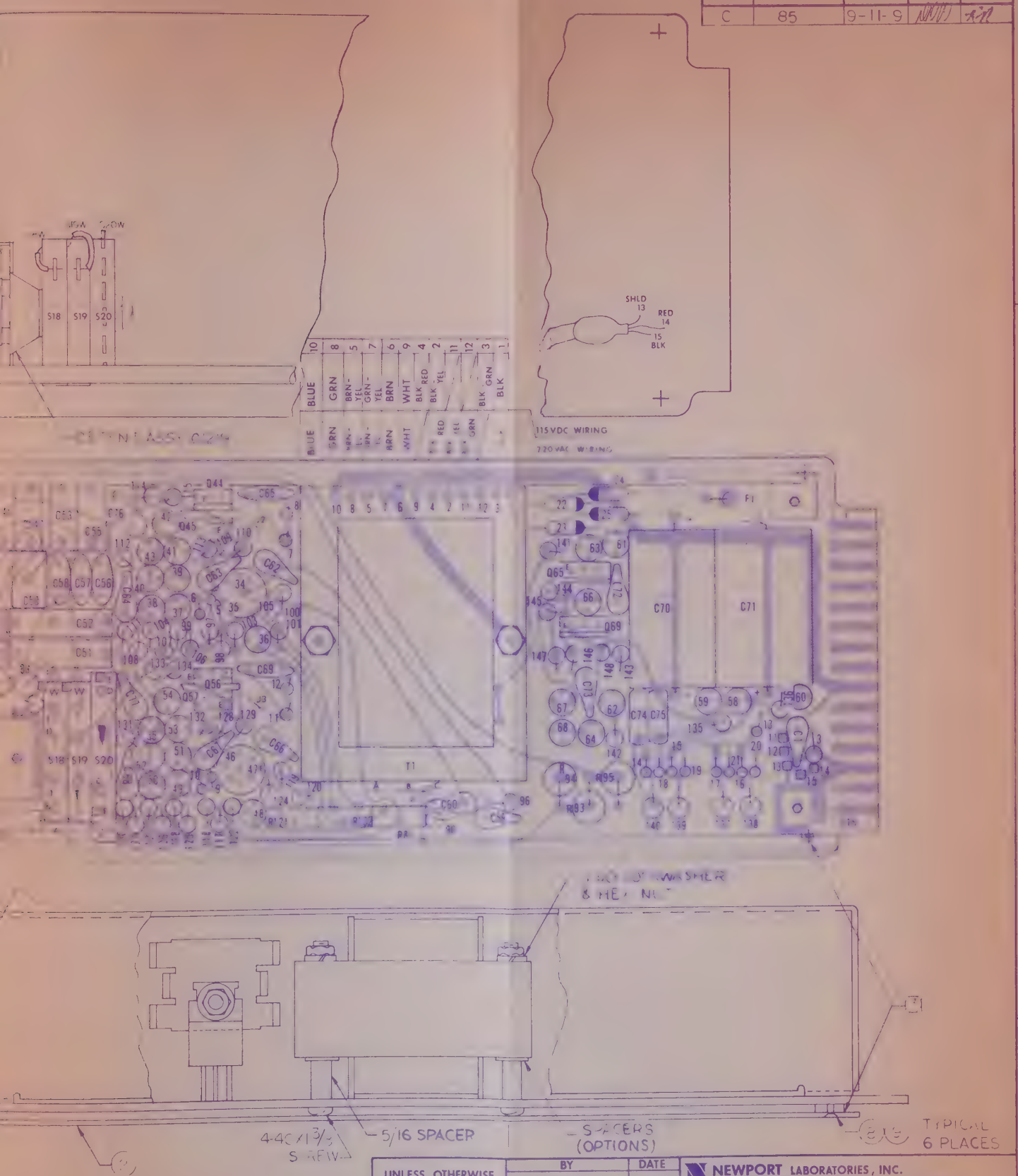
4 WIRE SWITCH WIPE

ELECTRICAL CONTACT TO GUARD LAND 2 TO PANEL

2 INDICATES DIRECTION FOR MECHANICAL HANDLING

NOTE

| CHG | E.O NO. | DATES | BY | CHK |
|---|---|---|---|---|
| C | 85 | 9-11-9 | [illegible] | [illegible] |







BOARD AS SHOWN
E FROM LOWER L.H. CORNER OF P.C. TO
ITCH ROTOR KEY (S1-S20)
TOP ASSY P/L

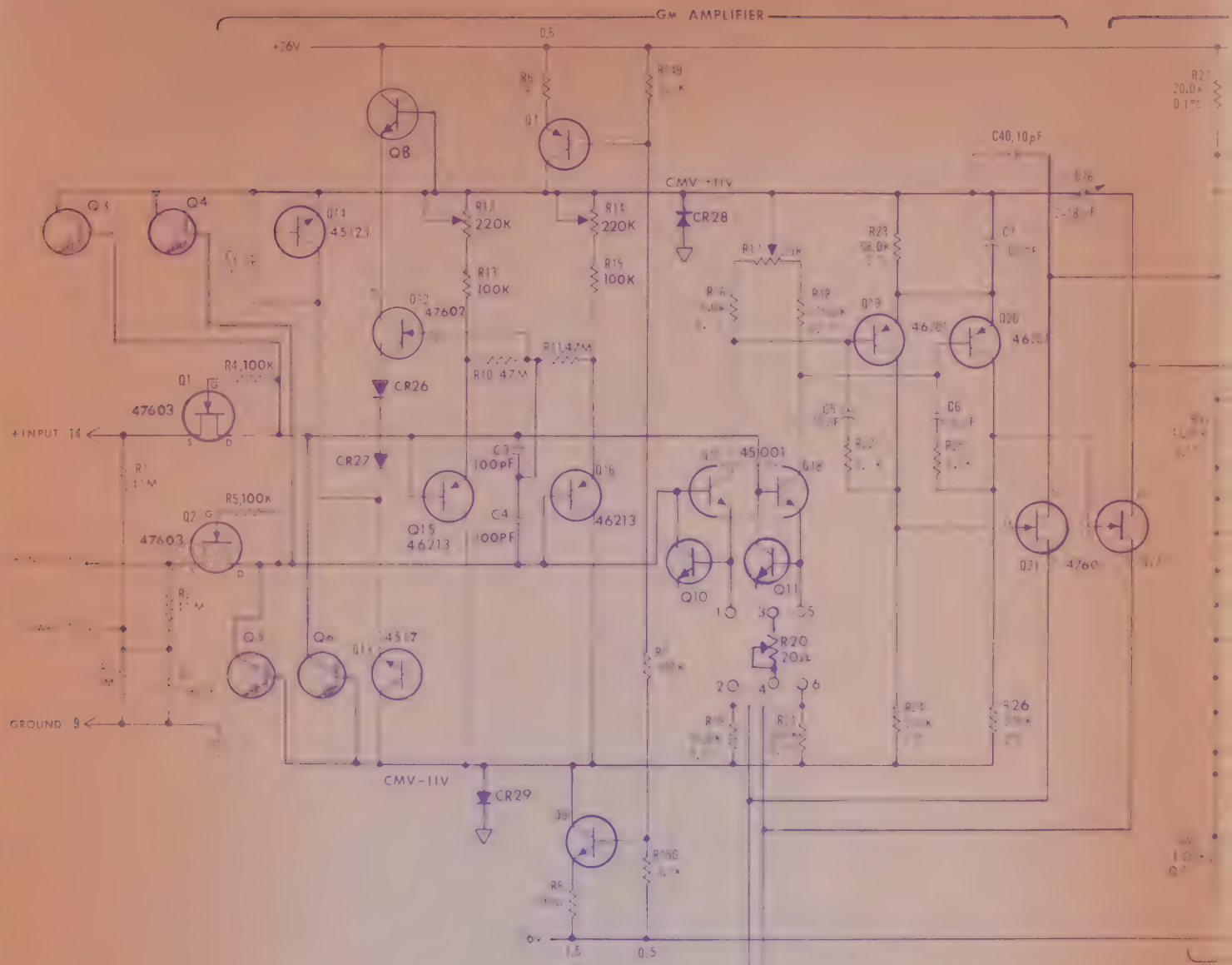
| UNLESS OTHERWISE SPECIFIED: | BY | DATE |
|---|---|---|
| | DR DDW | 8-15-68 |
| TOLERANCES .X ± .05 ANGULAR ± 0° 30' .XX ± .02 .XXX ± .005 ✓ THREAD CLASS 2A OR 2B REMOVE BURRS AND SHARP EDGES .02 MAX. DO NOT SCALE DWG | CHK RN | |
| | APPD B.V | |
| MATERIAL | USE OF THIS PROPRIETARY INFORMATION IS RESTRICTED TO MAINTENANCE OF OUR PRODUCTS OR FABRICATION TO OUR ORDER. | |
| | FINISH | |

NEWPORT LABORATORIES, INC.
630 E. YOUNG ST. SANTA ANA, CALIF. 92705

TITLE
AMPLIFIER ASSEMBLY – SERIES 60

| SIZE | NO. |
|---|---|
| D | 01092 |

SCALE 2/1 | MODEL 60 | SHEET 1 OF 1




| GAIN | RESISTANCE |
|---|---|
| 1 | ∞ |
| 2 | 100.0 K |
| 3 | 50.0 K |
| 5 | 25.0 K |
| 10 | 11.1 K |
| 20 | 5.49 K |
| 30 | 3.45 K |
| 50 | 2.04 K |
| 100 | 1.01 K |
| 200 | 502 |
| 300 | 334 |
| 500 | 200 |
| 1000 | 100 |
| 2000 | 50.0 |

TABLE I

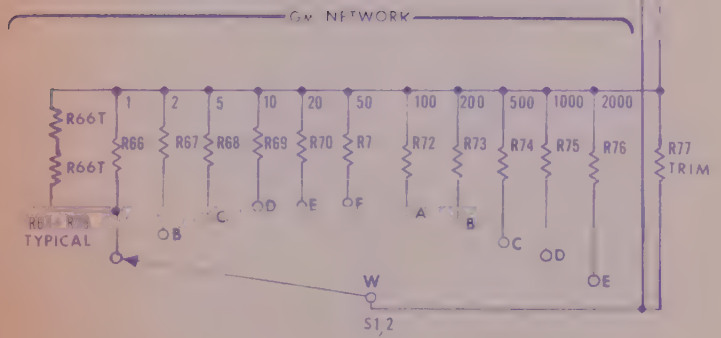
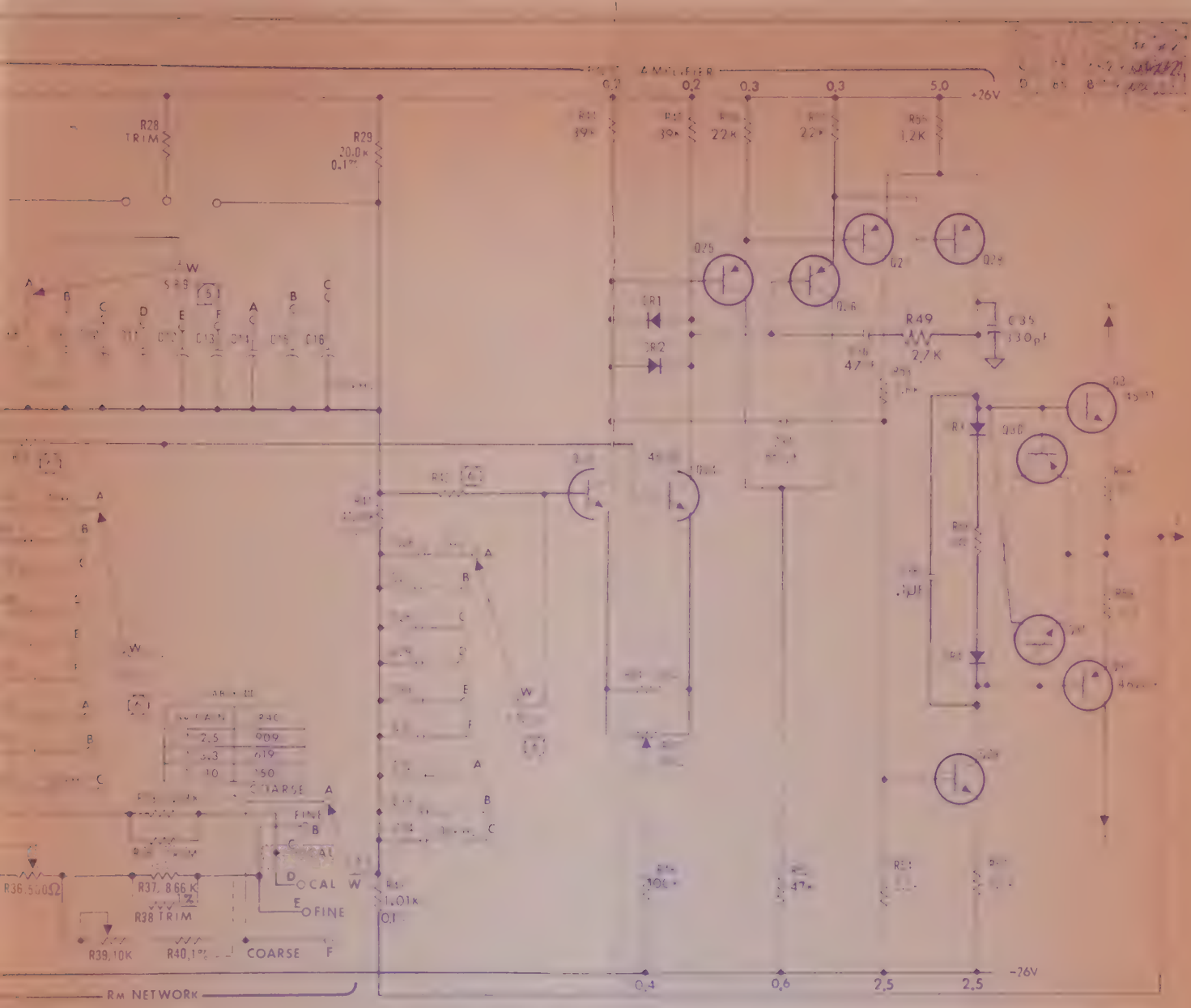



TABLE II FILTER CAPACITOR (

| | | | | |
|---|---|---|---|---|
| SINGLE POLE FILTER | C17-C34 | 0.33μ | 0.10μ | .033 |
| DOUBLE POLE BUTTERWORTH | C17-C34 C8-C16 | | | |
| DOUBLE POLE BESSEL | C17-C34 C8-C16 | .68 | .22 | |
| 3 POLE BUTTERWORTH | | | | |
| 3 POLE BESSEL | | | | |
| 4 POLE BUTTERWORTH | | .47μ | | |
| 4 POLE BESSEL | C8-C16 | .33μ .68μ | .22 | |

A B C

C77
151 (OMIT R49)
R29




ABADS)

| | 1KH: | 3▸H: | 10▸H: | 30▸H: | 100▸Hz | R30, 42 |
|---|---|---|---|---|---|---|
| | .0033μ | .001μ | 330p | 100p | 33μ | 0% |
| .01μ | .0033μ | .001μ | 330p | 100p | 33μ | 9.53K 1% |
| .033μ | .010μ | .0033μ | .001μ | 330p | 100p | |
| | .0033μ | .001μ | 330p | 100p | 33p | 9.53K |
| | | 680p | 220p | 68p | | |
| | | | | | | |
| | | | 330p | 100p | 22p | |
| | | | 470p | 120p | 22p | |
| | | | | | 100p | 1% |
| | | | 330p | 82p | 5p | 6.49K |
| | | | | | 68p | 1% |

F F A B C

SEE TABLE II FOR VALUES OF R30, R42 & C8 THRU C34.

5 COMPONENTS IN TABLES I II & III ARE OPTIONAL

4 ALL RESISTORS ARE 10%, 1/2 W.

3 ALL DIODES ARE NL 500-47000

2 ALL PNP TRANSISTORS ARE NL 205, 46205

1 ALL NPN TRANSISTORS ARE NL-105, 45105

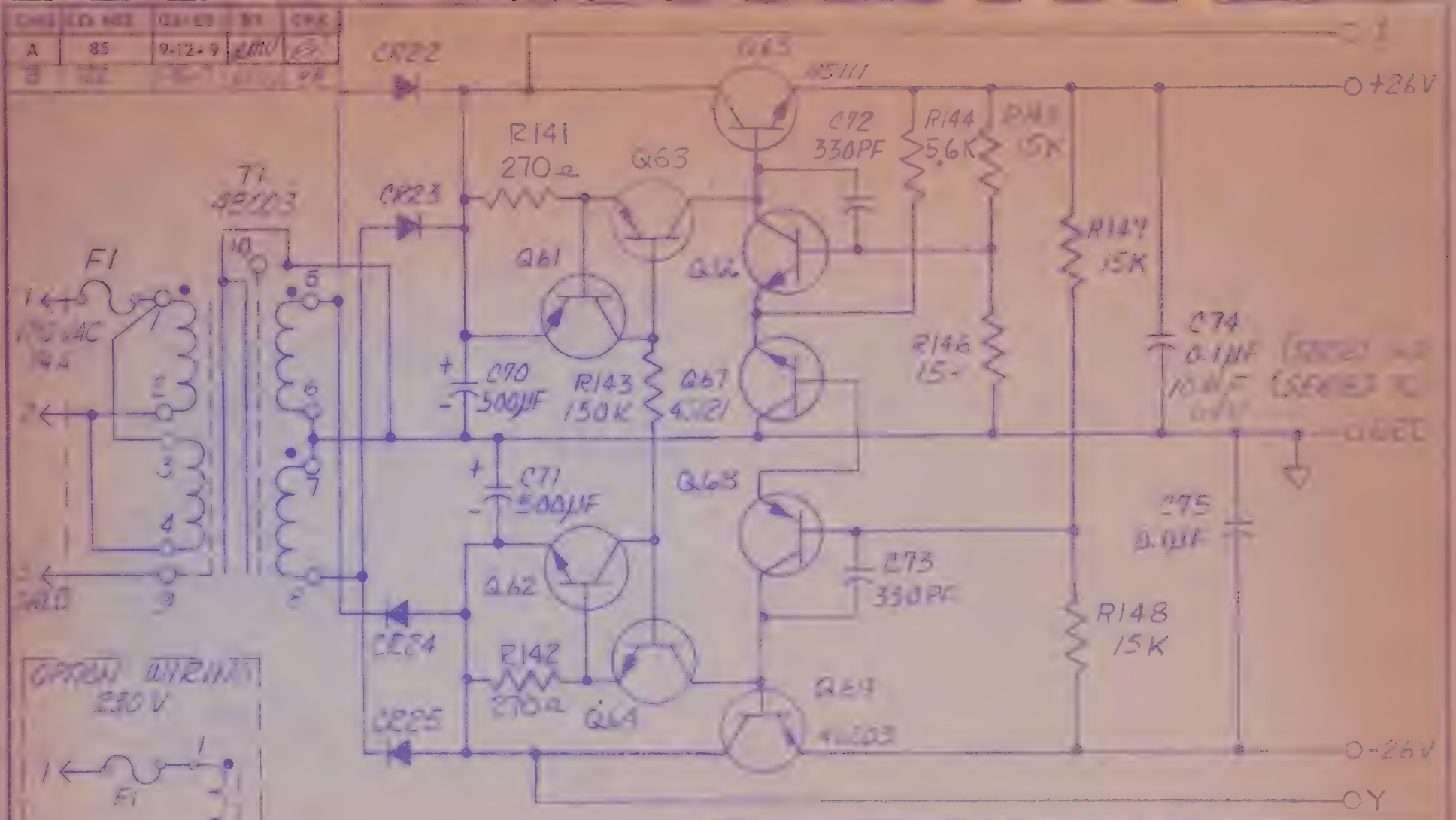
NOTE UNLESS OTHERWISE SPECIFIED

NEWPORT LABORATORIES INC
630 E YOUNG ST
SANTA ANA CALIF

FEB 12 '69

SERIES 60 SCHEMATIC DIAGRAM

01093-01


CR22
Q65
2N111
+26V
R141
270Ω
T1
4P103
CR23
Q63
C72
330PF
R144
5.6K
R145
15K
F1
Q61
Q66
R147
15K
C74
0.1μF
R146
15K
C70
500μF
R143
150K
Q67
4N21
C71
500μF
Q62
Q65
C73
330PF
C75
0.1μF
R148
15K
CR24
R142
270Ω
Q64
CR25
4N103
0-26V
Y
OPTION WIRING
230 V
F1
4. DIODES ARE 47001
3. RESISTORS ARE 10%, 1/2W.
2. NPN TRANSISTORS ARE 46205
1. PNP TRANSISTORS ARE 45105
NOTE: UNLESS SPECIFIED
NEWPORT LABORATORIES INC.
630 E YOUNG ST., SANTA ANA CALIF. 92705
SCALE: NONE
APPROVED BY:
DRAWN BY WJF
DATE: MAY 12 69
CHK'D
DRAWING NUMBER
D1053-6

| CIRCUIT NO | ITEM NO | DESCRIPTION | PART NO. | REV | MFR CODE | QTY |
|---|---|---|---|---|---|---|
| | | Board, Printed Wiring | 01094 B | | | 1 |
| | | Schematic Diagram | 5303-01 | | | REF |
| | | CAPACITORS | | | | |
| C5,6,10 | | 1.1pF, ±pF, 500V, Ceramic | 5151109 | | | 3 |
| C 3,9 | | 100pF, 10%, 500V, Ceramic | 5152101 | | | 2 |
| C8 | | 47 pF, " | 5152479 | | | 1 |
| C4,37 | | 680 pF, " | 5152681 | | | 2 |
| C38 | | 0.1mF +80% -20% 10V Ceramic | 5033174 | | | 1 |
| C 2, | | 0.1,pf,10%,250V, MYLAR Dipped | 5111 | | | 1 |
| C 36 | | 2-18.5pF, Variable | 7301189 | | | 1 |
| | | 330pF, 20%, 500V, Ceramic | 5152331 | | | 1 |
| | | DIODES | | | | |
| CR1-4,26,27,28,29 | | 50ma, 30V, Glass | 479000 | | | 8 |
| J1,2,3 | | Jumper, Zero Loops 1-2 3-5, 4-6 | | | | 3 |
| | | RESISTORS | | | | |
| R 58,59 | | 10Ω 10%, 1/2W, Carbon Film | 8021109 | | | 2 |
| R 34 | | 100Ω " " " | 8021101 | | | 1 |
| R 9 | | 33Ω " | 8021391 | | | 1 |

| REV | E.O. NO. | BY/CHK | DATE |
|---|---|---|---|
| A | 24 | [illegible] | [illegible] |
| B | 23 | [illegible] | [illegible] |
| C | 33 | [illegible] | [illegible] |
| D | [illegible] | DW/[illegible] | 6-1[illegible] |
| E | 86 | [illegible] | 9-12-7 |

BY [illegible]
CHK DW
APPD [illegible]
DATE [illegible]

NEWPORT LABORATORIES INC
630 E.YOUNG ST. SANTA ANA, CALIF. 92705

TITLE [illegible] PARTS LIST NO. [illegible]

MODEL [illegible] ASSY [illegible] SHEET 1 OF 2

| CIRCUIT NO. | ITEM NO. | DESCRIPTION | PART NO. | MFR CODE | QTY |
|---|---|---|---|---|---|
| | | | | | |
| | | RESISTORS | | | |
| R6 | | 1Ω, 10% 1/2W, Carbon Film | 8021107 | | 1 |
| R 37, 38, 39, 40, 41 | | 2.2K " | 8021272 | | 5 |
| R 42, 43 | | 3.3K " | 8021332 | | 2 |
| R 48 | | 5.6K " | 8021562 | | 1 |
| R 44, 45 | | 39K " | 8021393 | | 2 |
| R 50, 51 | | 22K " | 8021223 | | 2 |
| R 31 | | 47K " | 8021473 | | 1 |
| R 30 | | 1.2K " | 8021122 | | 1 |
| R 33, 35, 7, 4, 5, 49 | | 100K " | 8021104 | | 6 |
| | | | | | |
| R 1, 2, 3, 10, 11 | | 47Ω, 10%, 1/4W COMP | 8141479 | | 5 |
| R 32, 43 | | 1.01K, 0.1%, 1/8W, Wirewound | 8510109 | | 2 |
| R 23 | | 68.1K, 2%, 1/4W, Metal F. | 8240681 | | 1 |
| R 24, 26 | | 270K " | 8240274 | | 2 |
| R 27, 29 | | 2K, 0.1%, 1/8W, Wirewound | 8520001 | | 2 |
| R 19, 21 | | 50K " | 8550001 | | 2 |
| R 15, 16 | | 175K " | 8517502 | | 2 |
| R 47 | | 100Ω, Var., 10%, 3/4 W Cer. | 8332101 | | 1 |
| R 13, 24 | | 220K Var., 20%, .1W Arbor | 8301224 | | 2 |
| R 50 | | 10Ω, Var., 10% 3/4W | 8332209 | | 1 |
| R 17 | | 200K, Var., 10%, 3/4W | 8332203 | | 1 |
| R 28, 34 | | 41.50K, 0.1%, 1/8 W, WIREWOUND | 8541501 | | 2 |
| | | | | | |

| REV | E.C. NO. | BY/CHK | DATE |
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BY
CHK
APPD
DATE

NEWPORT LABORATORIES INC
630 E YOUNG ST. SANTA ANA, CALIF 92705

TITLE: BASIC AMPLIFIER

PART LIST NO. 110041

ASSY TO 110041

SHEET 2 OF 3

| CIRCUIT NO. | ITEM NO. | DESCRIPTION | PART NO. | MFR. CODE | QTY |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | RESISTORS | | | |
| | | Jumper | | | |
| | | | | | |
| | | | | | |
| | | TRANSISTORS | | | |
| Q 17,18,23,24 | | NPN, Twin | 45100 | | 2 |
| Q 36 | | NPN, Med. Power TIP 29A | | | 1 |
| Q 8,9,14,15,31,32 | | NPN, Low level 2N5133 | 45105 | | 11 |
| Q 16,26 | | PNP SELECTED 2N5138 | 46201 | | 2 |
| Q7,25-28,30 | | PNP Low Level 2N5138 | 46205 | | 8 |
| Q33 | | PNP, Med Power 46205 | 46209 | | 1 |
| Q15,16 | | PNP, SELECTED 46205 | 46213 | | 2 |
| Q21, 22 | | Nch Fet Pair 47602 | 47601 | | 1 PR |
| Q 12 | | N channel Fet 2N5457 MPF103 | 47602 | | 1 |
| Q 1,2 | | Nch Fet 2N5459 MPF105 | 47603 | | 2 |
| Q11,13 | | NPN, SELECTED 2N5133 | 45121 | | 2 |
| Between Q 12 & 13 | | Heat Dissipator, Xistor | 90024-7 | | 1 |
| | | | | | |
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| REV | E.O. NO. | BY/CHK | DATE |
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DATE

NEWPORT LABORATORIES INC.
630 S. YOUNG ST. SANTA ANA, CALIF. 92705

TITLE Basic AMPLIFIER

PART LIST NO. 03-093

MODEL 340-00 ASSY 11093 SHEET 1 OF 1

| CIRCUIT NO. ITEM NO. | DESCRIPTION | PART NO. REV | MFR CODE | QTY |
|---|---|---|---|---|
| T1 | TRANSFORMER, POWER | 48003 | | 1 |
| | | | | |
| F1 | Fuse, 1/4A, AXIAL LEADS LITTLE FUSE | 9000042 | | 2 |
| | | | | |
| | RESISTORS | | | |
| R 141, 142 | 270 ohms, ±10%, 1/2 W CARBON FILM | 8021271 | | 2 |
| R 144 | 5.6K " " | 8021562 | | 1 |
| R 145, 146 | 56K " " | 8021563 | | 2 |
| R 147, 148 | 100K " " | 8021104 | | 2 |
| R 149 | 150K " " | 8021154 | | 1 |
| | | | | |
| | CAPACITORS | | | |
| C 73, 74 | 330 pf, ± 20%, 500V, CERAMIC | 5152331 | | 2 |
| C 75, 76 | .1 µf, 10%, 250V, DIPPED MYLAR | 5511104 | | 2 |
| C 70, 71 | 500 µf, + 50% - 10%, 50V, ELECTROLYTIC | 5283501 | | 2 |
| | | | | |
| | RECTIFIERS | | | |
| CR 22-25 | 400ms, 100V, Glass | 47001 | | 4 |
| | | | | |
| | TRANSISTORS | | | |
| Q62, 64, 66, | NPN, 2N5133 | 45113 | | 3 |
| Q65 | NPN, Power TIP29A | 45111 | | 1 |
| Q61, 63, 68 | PNP, 2N5138 | 46203 | | 3 |
| Q69 | PNP, Power TIP30A 46205 | 46203 | | 1 |
| Q67 | NPN 2N5133 | 45113 | | 1 |

| REV | E.O. NO. | BY/CHK | DATE |
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BY
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DATE 4-24-68

NEWPORT LABORATORIES INC
630 E.YOUNG ST SANTA ANA, CALIF. 92705

TITLE POWER SUPPLY, 60

PART LIST NO.

MODEL

SHEET 1 OF 1

P/L NO. 01177-01

| CIRCUIT NO. | ITEM NO. | DESCRIPTION | PART NO. | MFR CODE | QTY |
|---|---|---|---|---|---|
| 60---+70 Series | | | | | |
| | | | | | |
| | 1151 | Select in Test | | | 1 |
| R7 | R152 | 100.0K, 0.1%, 1/4W, Wirewnd. | 8510002 | | 1 |
| R8 | R153 | 25.00K, " | 8525001 | | 1 |
| R9 | R154 | 11.11K, " | 8511111 | | 1 |
| R70 | R155 | 5.203K, " | 8552639 | | 1 |
| R71 | R156 | 2.041K, " | 8520419 | | 1 |
| R72 | R157 | 1.010K, " | 8510109 | | 1 |
| R73 | R158 | 502.5Ω, " | 8550258 | | 1 |
| R74 | R159 | 200.4Ω, " | 8520048 | | 1 |
| R75 | R160 | 100.1Ω, " | 8510018 | | 1 |
| R76 | R161 | 50.03Ω, " | 8550037 | | 1 |
| S1-2 | S1-2 | Switch Wafer | 01079 | | 2 |

| REVISION NO. | BY/CHK | DATE |
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BY DLW
CHK
APPD LSW
DATE Oct. 31, '68

NEWPORT LABORATORIES INC.
630 E. YOUNG ST. SANTA ANA, CALIF., 92705

TITLE Gm Network, 1, 2, 5, 10, 20, 50, 100, 200, 500, 1K, 2k, SEC.

PART LIST NO. 01177-01

MODEL 60-70 ASSY 01092, 01300

SHEET 1 OF 1

| CIRCUIT NO. | ITEM NO. | DESCRIPTION | PART NO. | MFR CODE | QTY |
|---|---|---|---|---|---|
| ANALOG PC | SERIES 60 | | | | |
| | | ----------CAPACITORS---------- | | | |
| C16 | C25 | 1.0uF, 10%, Mylar Wrapped | 6565163 | | 1 |
| C17,18 | C17,26 | .33uF, 5%,50V, Mylar Wrapped | 6545334 | | 2 |
| | | | | | |
| | | | | | |
| | | ----------RESISTORS---------- | | | |
| R60,70 | R30,42 | 9.53K,1%,1/8W,Metal Film | 8289531 | | 2 |
| | | | | | |
| | | | | | |
| | | ----------JUMPERS---------- | | | |
| | J1* | S8W to S8A | | | 1 |
| | J2* | S10W to S10A | | | 1 |
| | J3* | S12W to S12A | | | 1 |
| | | | | | |
| | | | | | |
| | | * Series 60 only | | | |
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| REV | ECO NO. | BY/CHK | DATE |
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| A | 11 | DW | |

BY DW
CHK
APPD
DATE 12/18/80

NEWPORT LABORATORIES INC.
630 S YOUNG ST SANTA ANA CALIF. 92705

TITLE: POLE BUTTERWORTH FILTER, 16HZ

PART LIST NO. 01157-21

MODEL 60 | REF 01152 | SHEET 1 OF 1

P/L NO. 01174

| CIRCUIT NO | ITEM NO | DESCRIPTION | PART NO. | MFR CODE | QTY |
|---|---|---|---|---|---|
| | | ----------RESISTORS---------- | | | |
| R60,64 | | 1Meg,0.1%,1/4W,Wirewound | 8410003 | | 2 |
| R61,63 | | 10.00K,0.1%,1/4W,Wirewnd. | 8510001 | | 2 |
| R62 | | 500Ω ,Var.,20%,3/4",Cer. | 8332501 | | 1 |
| | | ----------MISCELLANEOUS---------- | | | |
| C39,40 | | Capacitor,33pF,20%500V,Cer | 5152339 | | 2 |
| S4-7 * | | Switch Wafer | 01079 | | 4 |
| W2 | | Cable, Input | 01290-02 | | 1 |
| W3 | | Cable, Input | 01289-02 | | 1 |
| | | *NOTE: Install Detent Assy & Brkt Before Switch Wafer | | | |

| REV | E C NO | BY/CHK | DATE |
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DATE

NEWPORT LABORATORIES INC.
630 E.YOUNG ST. SANTA ANA, CALIF., 92705

TITLE
INPUT ATTENUATOR

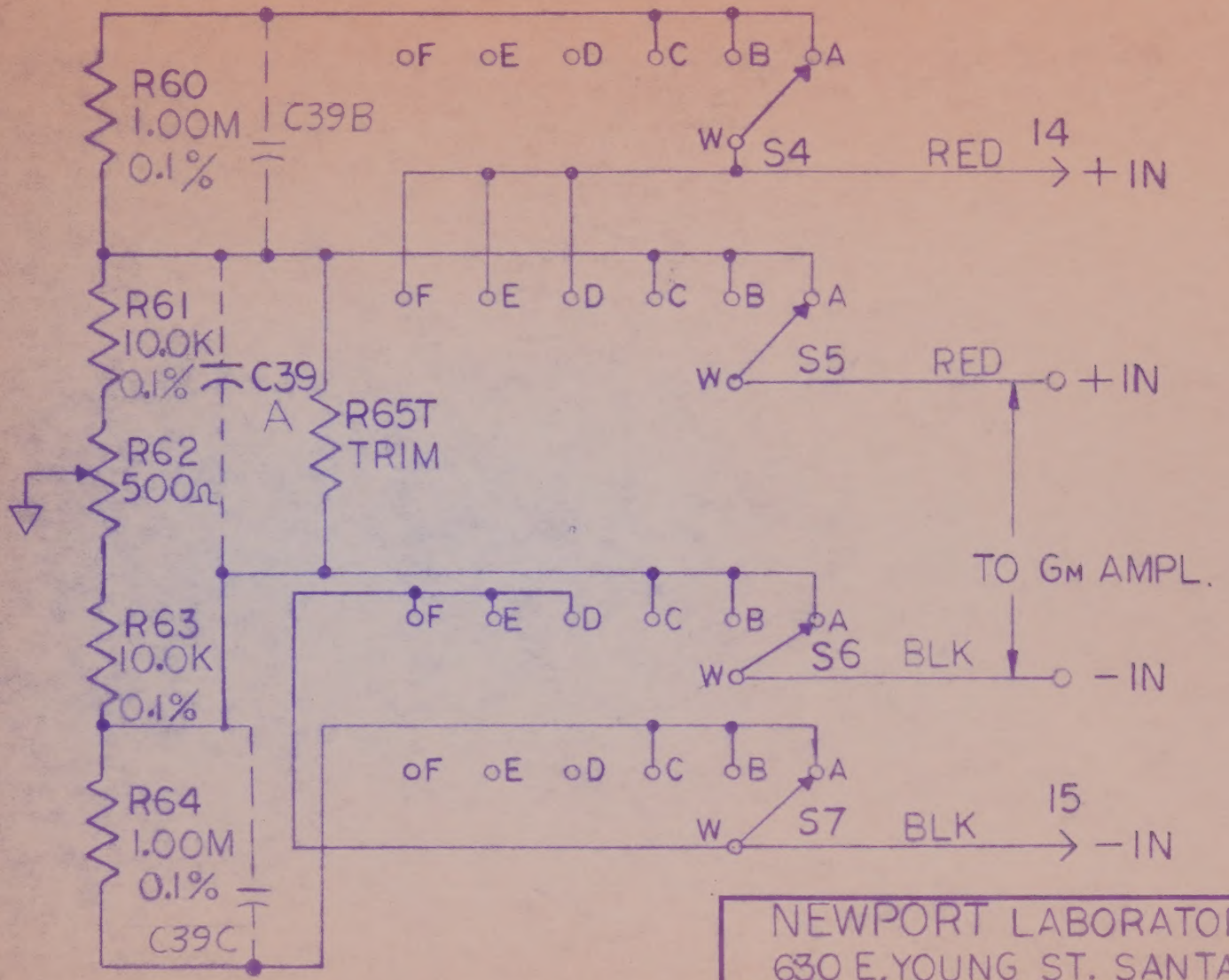
PART LIST NO.
01174-01

MODEL 10

ASSY 01092

SHEET 1 OF 1

D1




2. FOR PART LIST SEE 01174-01

1. C39A, B & C TO BE ADDED BY TEST WHEN REQUIRED.

NEWPORT LABORATORIES, INC.
630 E. YOUNG ST. SANTA ANA, CAL. 92705

| SCALE: — | APPROVED BY: | DRAWN BY |
|---|---|---|
| DATE: 5-23-69 | B L Wakes 9 Oct 69 | CHK |

SERIES 60

ATTENUATOR, SCH. DIAGRAM

DRAWING NUMBER 01093-10

PRINTED ON NO. 1000H CLEARPRINT